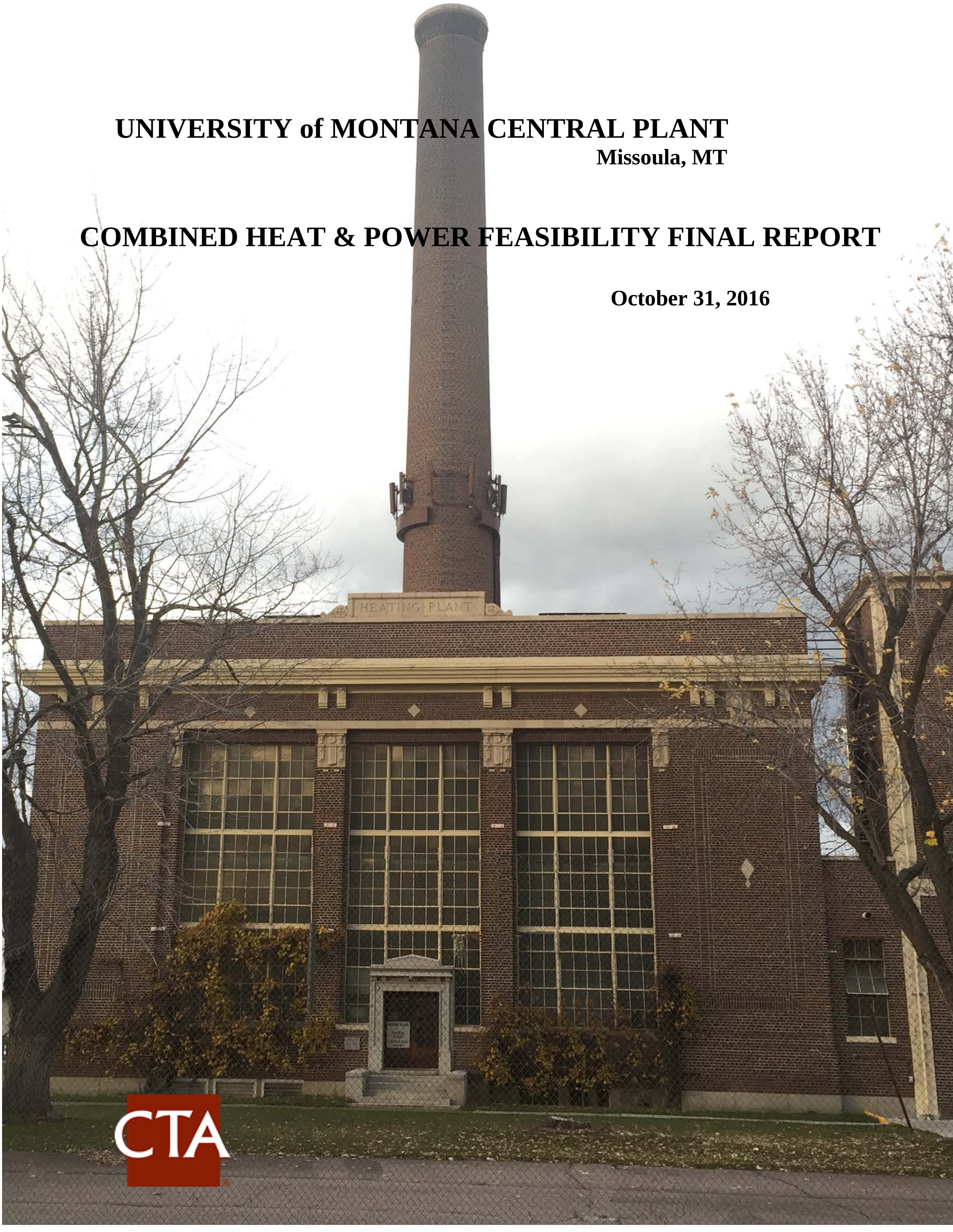
UNIVERSITY of MONTANA CENTRAL PLANT

Missoula, MT

COMBINED HEAT & POWER FEASIBILITY FINAL REPORT

October 31, 2016



CTA

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PROJECT INFORMATION

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INTRODUCTION

This report was funded through the Montana Department of Environmental Quality to determine the technical and economic feasibility of installing a combined heat and power plant (CHP) at the University of Montana. The proposed CHP installation would be located at the existing central boiler plant and would be integrated into the existing steam and electrical distribution systems to provide both heat and power to the campus.

The CHP installation would reduce operating costs and provide an on-site power generation plant that could increase the reliability of electric power for the campus. This report analyzes the important technical and economic factors that will guide the decision making process in the determination of the feasibility of a CHP installation.

Thank you to Brian Kerns and Mike Burke their insight into the boiler plant operations as well as ideas, identification of issues to resolve, and access to the existing plant, drawings, and other key resources.

Conceptual Drawing of two Gas Turbines located on the North Side of the Boiler Plant

EXECUTIVE SUMMARY & RECOMMENDATIONS

Table 1 below summarizes the installation costs, annual energy cost savings, net annual operational savings, and the simple payback for each investment. Three CHP units were evaluated:

- Twin OPRA16 (1.6 MW nominal capacity, each) gas turbines
- Solar Centaur 50 (4.6 MW nominal capacity) gas turbine
- Solar Mercury 50 (4.6 MW nominal capacity) gas turbine

TABLE 1: Economic Summary Results

CHP Analysis Summary Table					
Type	**Sell Power**	**Installed Cost**	**Energy Savings**	**Net Annual Operational Savings**	**Simple Payback**
Twin OPRA16 & Dual Pressure STG (dual fuel)	No Yes	$12,089,430 $12,089,430	$1,557,273 $1,770,185	$1,285,535 $1,531,115	9.4 7.9
Solar Centaur 50 & Dual Pressure STG (dual fuel)	No Yes	$12,945,965 $12,945,965	$1,392,315 $1,546,253	$1,023,041 $1,461,183	12.7 8.9
Solar Mercury 50 (nat. gas only)	No Yes	$11,757,691 $11,757,691	$1,380,504 $1,518,475	$724,616 $981,235	16.2 12.0

Notes

1. Dual fuel operation is not available for the Solar Mercury 50.
2. The Solar Mercury 50 has a Service Agreement cost of $55,000/mo or $660,000/yr which affects the net operational savings
3. The Solar Centaur 50 has a Service Agreement cost of $31,640/mo. $379,680/yr
4. The Service Agreement cost for the twin OPRA16 turbines is approximately $20,000/mo. Or $240,000 per year
5. The "Sell Power" option is priced at $0.055/kWh.

Each CHP unit was evaluated for "No Sales" option in which no excess electric power was sold back to the utility; and a "Sales" option in which electric power is sold back to the electric utility. A sales price of $0.055/kWh was selected as a possible wholesale rate. Discussions with Northwestern Energy indicated that they would have to perform a study to determine the electric buyback price within a power purchase agreement (PPA). The "No Sales" option also has a further penalty: since no power is allowed to reverse back onto the grid without a PPA, a buffer needs to be provided between the actual campus electric power demand and the electric generation output from the CHP plant. CTA feels this buffer should be approximately 75 kW so that the CHP plant load controls can react to the potential instantaneous campus power reductions when large equipment shuts off. The 75 kW buffer reduces the potential electric generation of the CHP plant to prevent electric power reversing back onto the grid.

As can be seen in Table 1, the twin OPRA 16 turbine CHP plant has the best performance in terms of simple payback (SPB). There are several contributing factors that produce this result.

The Service Agreement cost for the OPRA16 turbines is significantly less than both of the Solar turbines. The Solar Mercury 50 is a recuperative turbine that preheats the combustion air leading to higher electrical generation efficiency and, subsequently, lower levels of exhaust heat. The Mercury 50 Service Agreement costs $660,000/yr which is approximately $280,000/yr more than the Centaur 50, and $440,000/yr more than the twin OPRA16 turbines. Of course, this significantly affects the economics in the evaluation of each unit.

Another factor is that the twin OPRA16 turbines have more electric demand savings per year since only one of the turbines (50% of the generation capacity) will be down for maintenance at a particular time.

Both the Solar Centaur 50 and the OPRA16 turbines have been paired with a steam turbine generator (STG) as a way to increase the efficiency of each plant. Both of these CHP units provide more heat than is required during the summer months. The STG unit generates further electric power from the steam generated. The selected STG is a dual pressure turbine which means that there is a 30 psi extraction port to serve the campus heating loads; the balance of the steam produced is condensed to a lower pressure (below atmospheric pressure) resulting in even more electric power production.

Both the Solar Centaur 50 and the twin OPRA16 turbines have a dual fuel option which has been included in the installation cost for those units. The Mercury 50 unit does not have this option and would not be able to generate electric power during a gas curtailment. The cost for all three CHP units includes a dual-fuel duct burner integral to the heat recovery steam generator (HRSG) to provide steam heating capability during a natural gas curtailment.

The available natural gas supply pressure at the boiler plant is 75 psi. The gas turbines will require approximately 200 psi to operate. One way to achieve this is to install a natural gas compressor (with backup) to boost the pressure, however, this would cost approximately $650,000 to install and would require 80 kW of additional parasitic electric load which reduce the potential energy savings. An alternate choice does exist: the natural gas pressure supplied to the boiler plant can be raised to 200 psi by installing new district pressure regulators at the Arthur Avenue station. The cost of installing new regulators and reconfiguring the gas piping is approximately $200,000 and there is not any additional parasitic electric load.

The placement and general arrangement of the CHP unit and associated equipment (STG, HRSG, and condenser) is influenced by the State Historical Preservation Office (SHPO) since the boiler plant was constructed in 1922 and is on the historical registry. Additions to the building, or equipment placed near the front of the building will be under review. For this project, the turbines have been located at the rear (north) side of the building along with other existing equipment. Inside the boiler plant, existing boiler B-3 would be removed to make room for the HRSG and STG equipment.

The north side utility has many buried utilities including water, wastewater, electrical, and natural gas lines. Installation of the turbine(s) on a concrete slab would not be ideal or recommended in this area. The recommended support system would be a helical pier system with the piers strategically placed around buried lines. A steel framework would be built on top of the piers with a platform 5’ above the ground supporting the turbine(s).

FACILITY DESCRIPTION

The existing boiler plant consists of three steam boilers that produce saturated steam at 180 psig. Two of the boilers (B-1 and B-3) are rated at 70,000 lbs/hr while B-2 is rated at 30,000 lbs/hr. Currently B-2 operates closer to 25,000 lbs/hr after a VFD was added to its FD fan a few years ago. Boiler B-3 is currently configured to burn either natural gas or fuel oil No. 2 to provide heating capability with a natural gas curtailment call from Northwestern Energy. B-2 is connected to the existing 150-ft. chimney to vent combustion gases; B-1 and B-3 are vented to hoods located at the roof level of the boiler plant building.

Also located in the lower level of the boiler plant is steam turbine generator (STG) rated at 440 kW and 30,000 lbs/hr of steam. While steam is produced at 180 psig, only 30 psig is required to satisfy the campus steam demand. The STG provides this pressure reduction while also generating electric power. When the steam demand is above 30,000 lbs/hr, or the STG is not operating, the steam pressure is controlled by a pressure reducing valve (PRV) assembly before distribution to the campus.

Natural gas is currently supplied to the University at 75 psig. The capacity of the gas service is at least 1800 dkT/day based on historical usage. The existing intermediate pressure 4” service line enters the pressure regulator and then splits into two meters before recombining on the U of M side. The existing service has the capacity to handle the additional gas demand of a proposed gas turbine installation; however, the pressure is not sufficient. Approximately 200 sig is required to serve the gas turbine evaluated for this project. There are two options: 1) provide an on-site gas compressor to provide the necessary operating pressure; or 2) Northwestern Energy can increase the pressure of the existing 12” intermediate pressure main. This would require the installation of two additional district regulators and reconfiguration of the gas distribution piping in the vicinity of Arthur Avenue just south of the University campus.

E

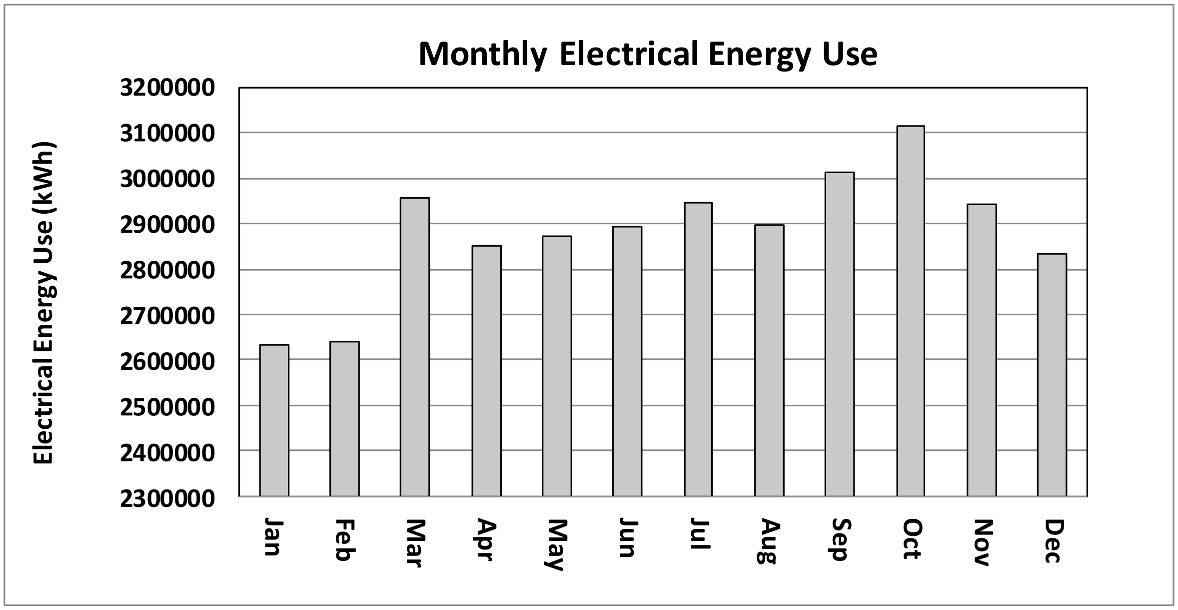
Natural Gas Service Entrance - North Side of Boiler Plant

ENERGY ANALYSIS

The energy analysis software utilized for this project was developed by the U.S, Department of Energy CHP Technical Assistance Program. Assistance was provided by Gil McCoy, PE and Carolyn Roos to facilitate the analysis. In addition, the Montana Department of Environmental Quality provided technical assistance organizing and analyzing the electric energy interval and steam production data. The Gilmore software tool is a spreadsheet-based program that determines CHP electrical generation and fuel use. The analysis includes rating the gas turbine generating capacity, heat rate, and unfired steam production based on altitude and varying ambient temperature. Supplemental spreadsheet analysis was used to calculate electrical generation capacity factors from the interval data (15 minute) provided. Additionally, the dual pressure steam turbine generator (STG) proposed for this project was analyzed in detail to determine the STG electrical production per month based on the heating steam load (based on 3-hr operator readings) and the availability of further power production from fully condensing steam not used for space heating.

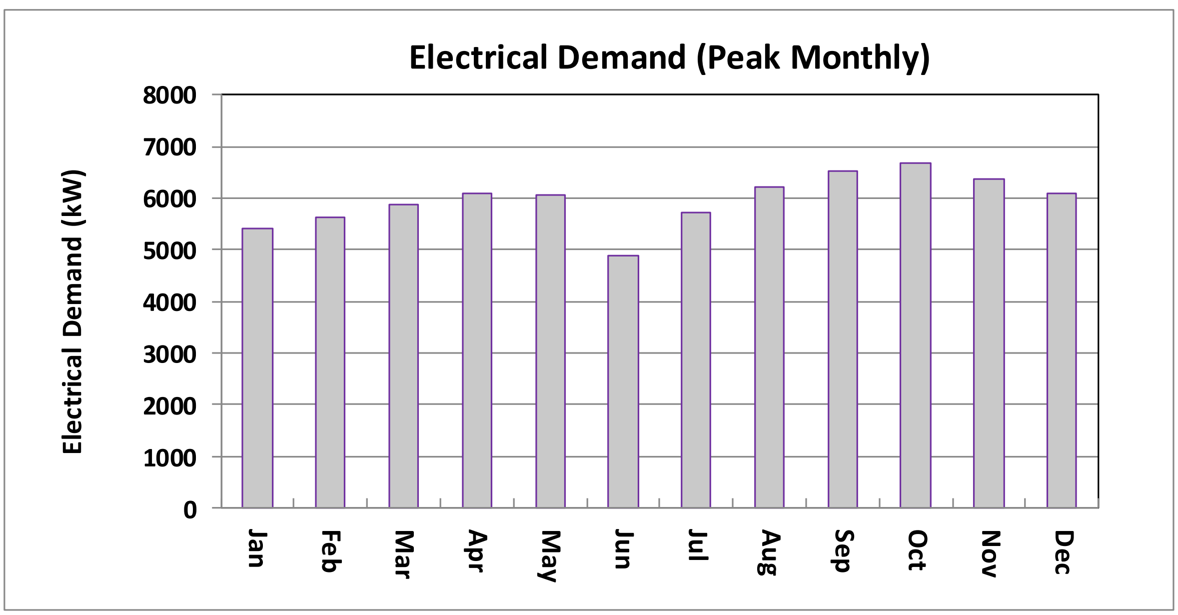
The University of Montana purchased approximately 34.5 million kWh of electrical energy in 2015 resulting in a cost of $3,261,008. The natural gas usage for 2015 was approximately 239,000 dkT at a total cost of $1,135,944, as shown below:

ENERGY USE AND COSTS FROM BILLING RECORDS							
	Electricity Demand		**Electricity**		**Natural Gas**		**Total Costs**
	($)	**(kW-mo billed)**	**($ total)**	**(kWh)**	**($)**	**(MMBtu)**	**($)**
Jan	$48,200	5,406	$235,865	2,632,931	$157,950	34,644	$393,815
Feb	$50,224	5,633	$257,849	2,639,536	$124,833	27,183	$382,682
Mar	$52,445	5,882	$276,886	2,956,254	$114,198	24,754	$391,084
Apr	$54,308	6,091	$278,418	2,851,472	$98,479	21,124	$376,897
May	$54,147	6,073	$283,582	2,873,179	$58,829	11,763	$342,411
Jun	$43,448	4,873	$271,902	2,894,002	$41,815	7,734	$313,717
Jul	$50,893	5,708	$281,130	2,944,950	$40,375	7,417	$321,505
Aug	$55,351	6,208	$257,049	2,896,608	$42,124	7,744	$299,173
Sep	$58,240	6,532	$281,092	3,013,397	$57,475	11,330	$338,567
Oct	$59,461	6,669	$296,315	3,114,498	$85,471	17,874	$381,786
Nov	$56,706	6,360	$269,138	2,943,228	$149,283	32,036	$418,421
Dec	$54,869	6,082	$271,782	2,833,890	$164,642	35,440	$436,424
Annual Totals	$638,294	5,960	$3,261,008	34,593,944	$1,135,474	239,043	$4,396,482



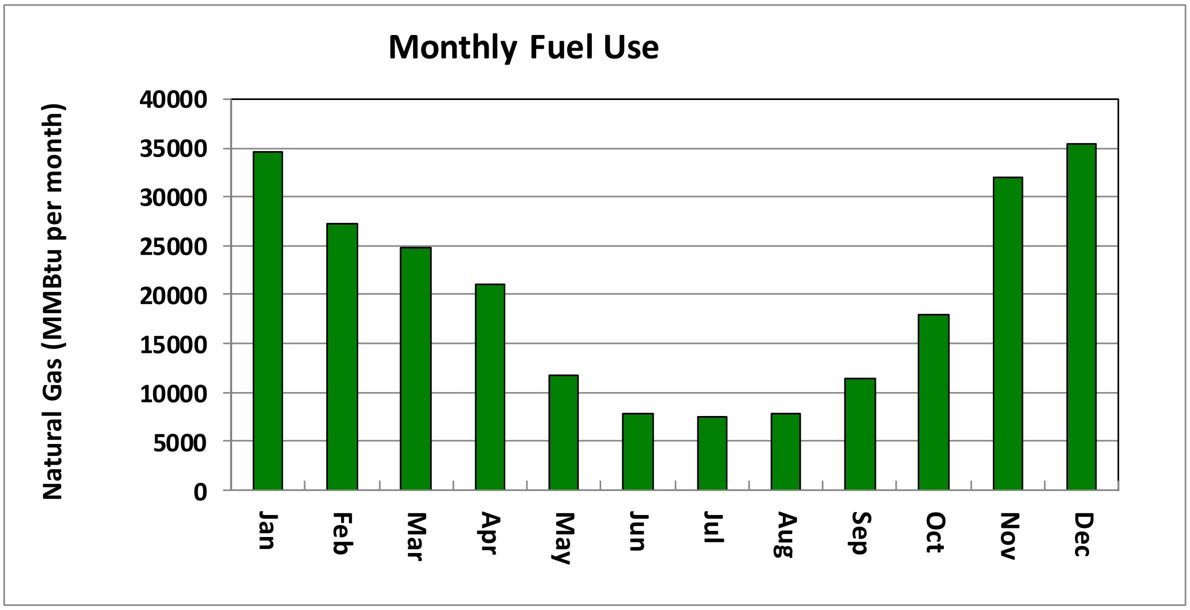
Annual Electric Use Profile by Month

As can be seen, electrical energy use increases during the summer corresponding to cooling loads, however, the peak load is in October probably a result of school in full attendance and warmer October weather in 2015.



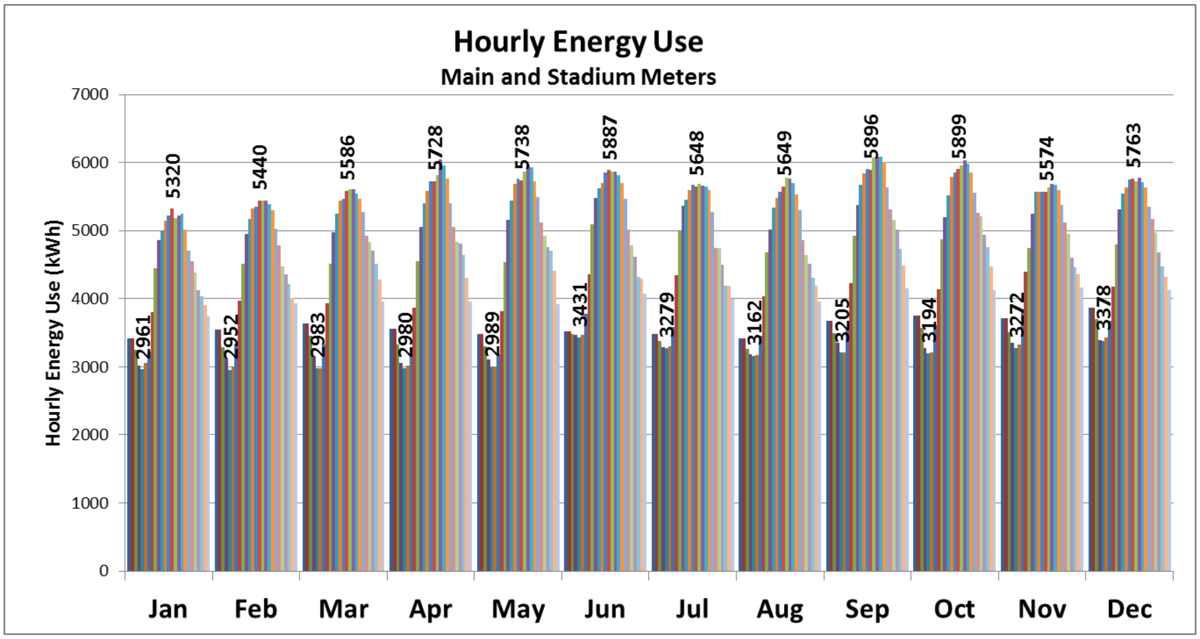
Annual Peak Electric Demand Profile by Month

Peak electric demand also occurs during September and October due to full occupancy and warmer weather.



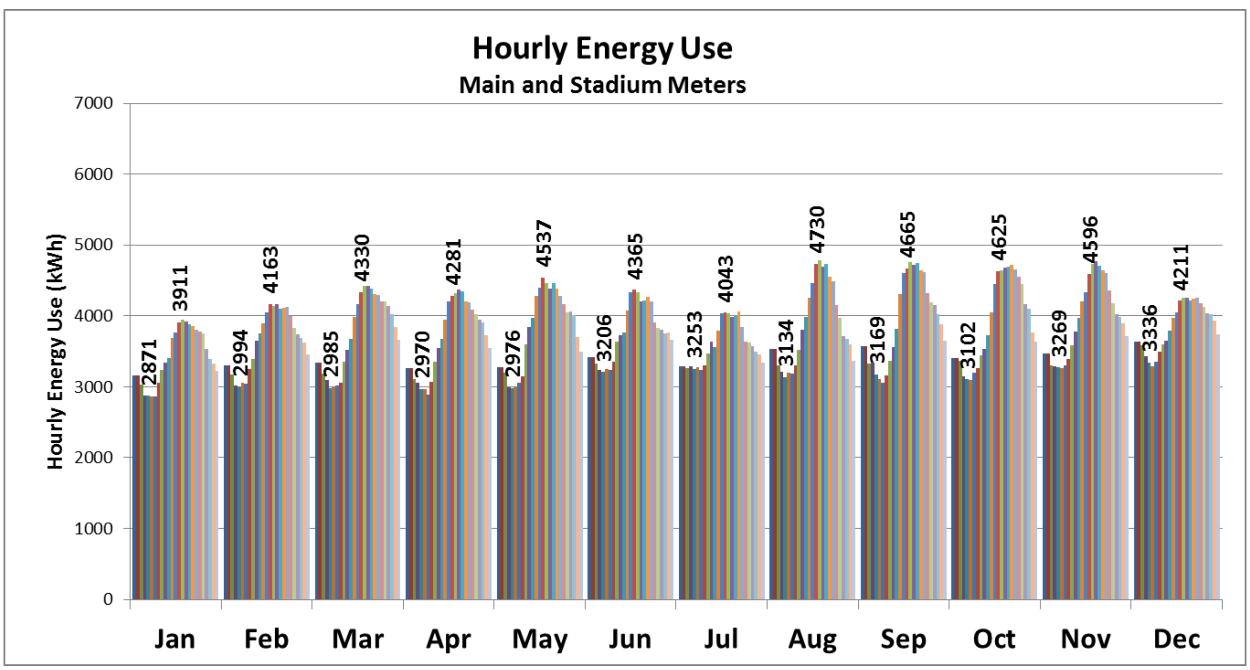
Annual Natural Gas Usage Profile by Month

Natural gas usage peaks during the winter as, expected, due to increased heating loads at this time of the year. Summer natural gas usage corresponds to 7,000-8,000 lbs/hr average steam load at the boiler plant.



Weekday Electric Use Profile by Month

The hourly electric profiles indicate the daily variation in electric demand and provides insight into the importance of a CHP generation system that can efficiently load follow when power purchase agreement is not in place with the utility and reverse power to the grid is not allowed.



Weekend Electric Use Profile by Month

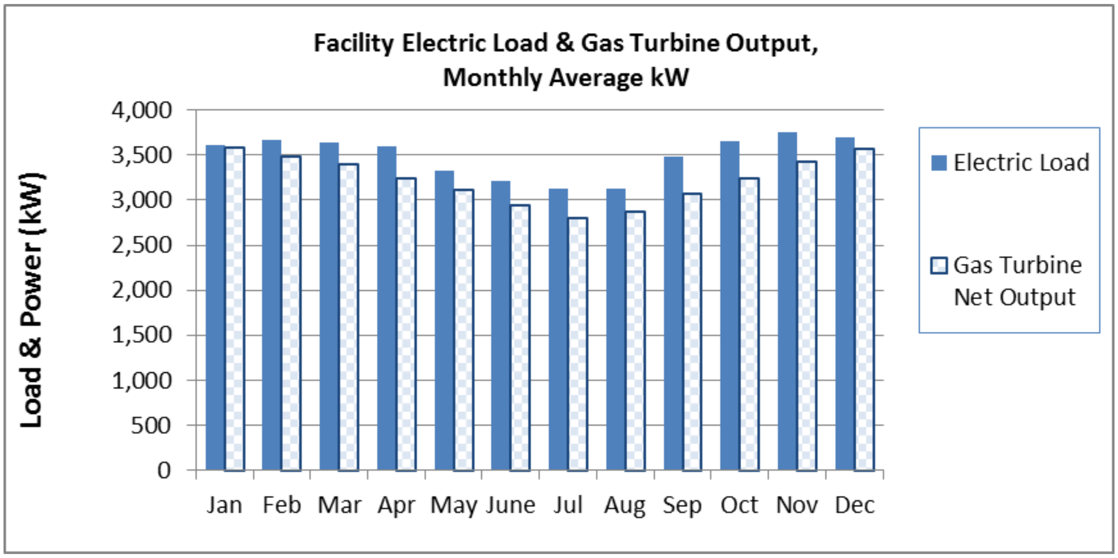
CHP Modeling Results

A. OPRA Turbines "No Sales"

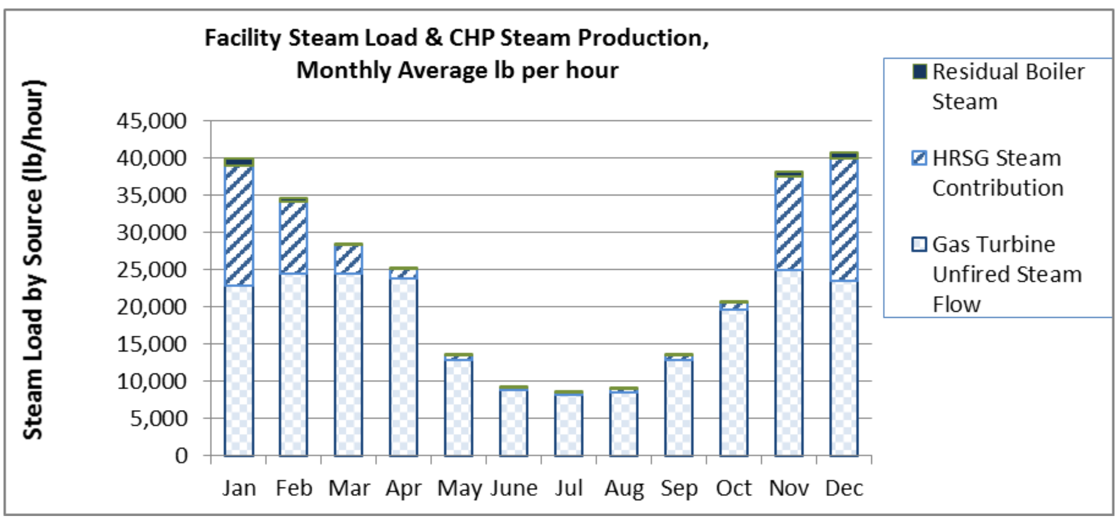
This option is composed of two OPRA16 turbines with a new dual-pressure STG and firetube HRSG with integral dual-fuel burner, bypass dampers and stacks, and economizer. Auxiliary equipment includes a surface condenser and cooling tower. Natural gas supply pressure is boosted by Northwestern Energy to 200 psi. Simple payback is 9.4 years and overall CHP efficiency is 60%. Although the turbine electric generation capacity is less than the single turbines (Solar Centaur 50 and Mercury 50), the STG produces power to make up this difference and provides quicker load-following capability. Electric demand savings are $351,073.

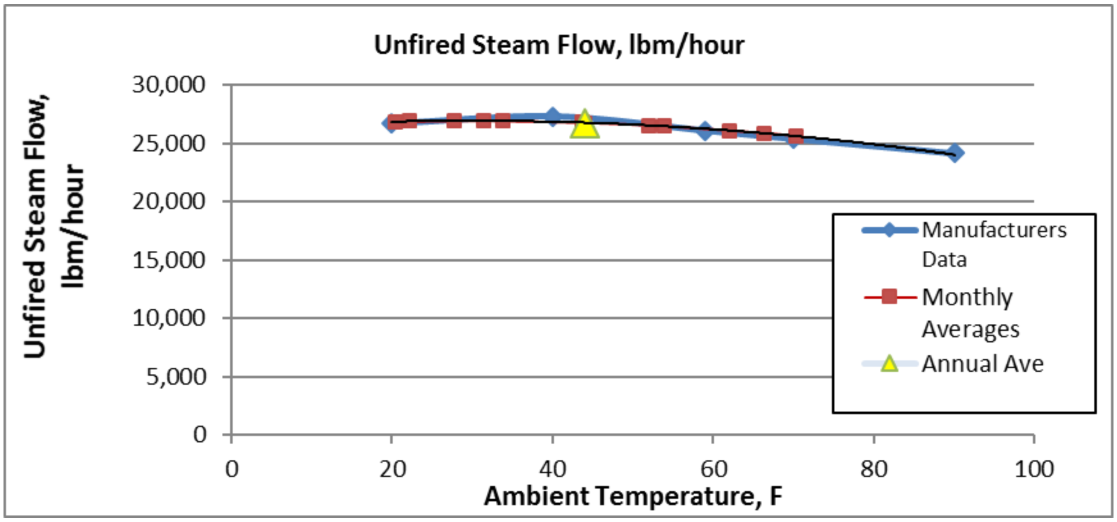
ENERGY ANALYSIS SUMMARY		
Plant Loads		
Average Plant Electricity Load, Avg kW	4,107	kW Avg
Average Plant Thermal Load, MMBtu/h	23.0	MMBtu/h
Displaced Thermal Efficiency	84.0%	
Baseline Energy Use & Costs	**Energy Use**	**Cost**
Baseline Electricity Energy Use, kWh/year, and Cost, $/year	35,961,680	$2,741,247
Baseline Electricity Demand Cost, $/year		$648,861
Baseline Fuel Use, MMBtu/year, and Cost, $/year	239,043	$1,135,474
CHP Alternative Energy Use & Costs	**Energy**	**Cost**
CHP Electricity Generated, kWh/year	31,438,706	
CHP Electricity Energy Purchased, kWh/year	4,522,975	$344,821
Demand Charges Not Offset by CHP, $		$297,688
CHP Electricity Sales, kWh/year	0	$0
CHP Fuel Used, MMBtu/year	416,207	$1,976,981
HRSG Fuel Used, MMBtu/year	59,186	$281,134
Residual Boiler Fuel to Serve Thermal Needs Not Met by CHP, MMBtu/year, and Cost, $/year	2,591	$12,308
Incremental O&M Cost, $/year		$271,738
System Performance		
Average Heat Rate, Btu/kWh, with parasitic loads at ambient temperature, elevation, part load	13,239	Btu/kWh
Fuel Rate at Full Fire, MMBtu/h	50.28	MMBtu/h
Fuel Rate at Part Load, MMBtu/h	50.02	MMBtu/h
Average CHP Thermal Output	24.07	MMBtu/h
CHP Thermal Output per kWh	8,093	Btu/kWh
Annual Heat Recovered By CHP (MMBtu/year)	153,556	MMBtu/year
Average Electrical Efficiency, Btu/kWh, with parasitic loads at temperature, elevation, part load	25.8%	
Average Thermal Efficiency	34.7%	
Average CHP Thermal Efficiency	60.5%	
Fuel Chargeable to Power Heat Rate (Btu/kWh)	7,930	Btu/kWh
CHP System Operation		
Availability	95.0%	
Average Operation as Percent of Capacity (Capacity Factor)	97.3%	
Plant Electricity Needs Met by CHP	87.4%	
Plant Thermal Needs Met by CHP	83.4%	
Payback		
Total Installed Cost	$12,090,000	
Avoided Costs	$0	
Grants	$0	
Annual O&M Costs	$271,738	
Energy Cost Savings	$1,557,273	
Sales Revenue	$0	
Total Operating Savings	$1,285,535	
Payback Before Incentives (years)	9.40	years
Payback with Incentives (years)	9.40	years

Efficiencies	**CHP Annual**
Electrical Efficiency at Part-Load, Mean Monthly Temperature after Auxiliary Loads	26%
Thermal Efficiency	35%
Overall Efficiency	60%
Heat Rate, Btu/kWh	13,239

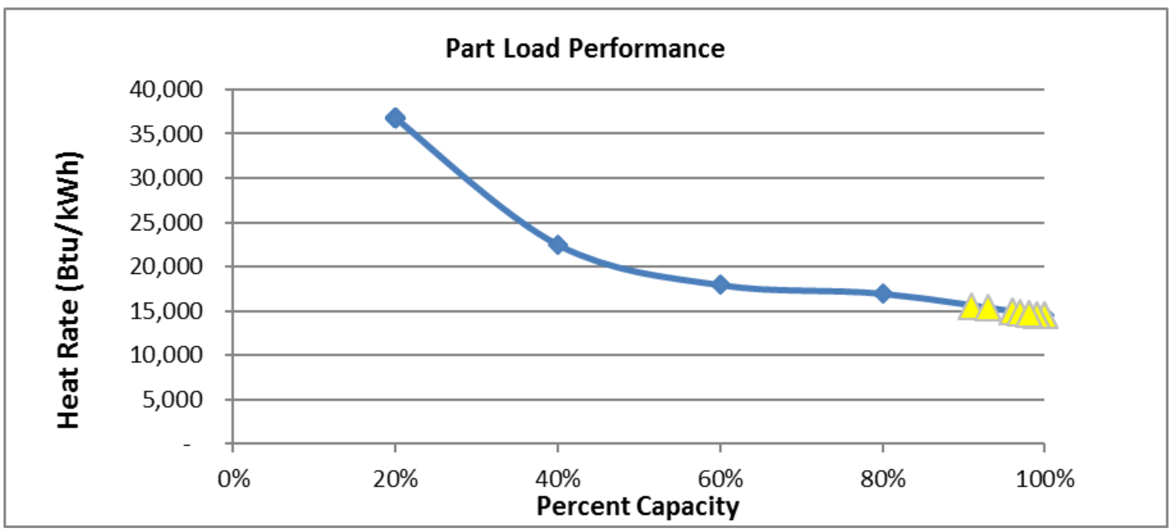


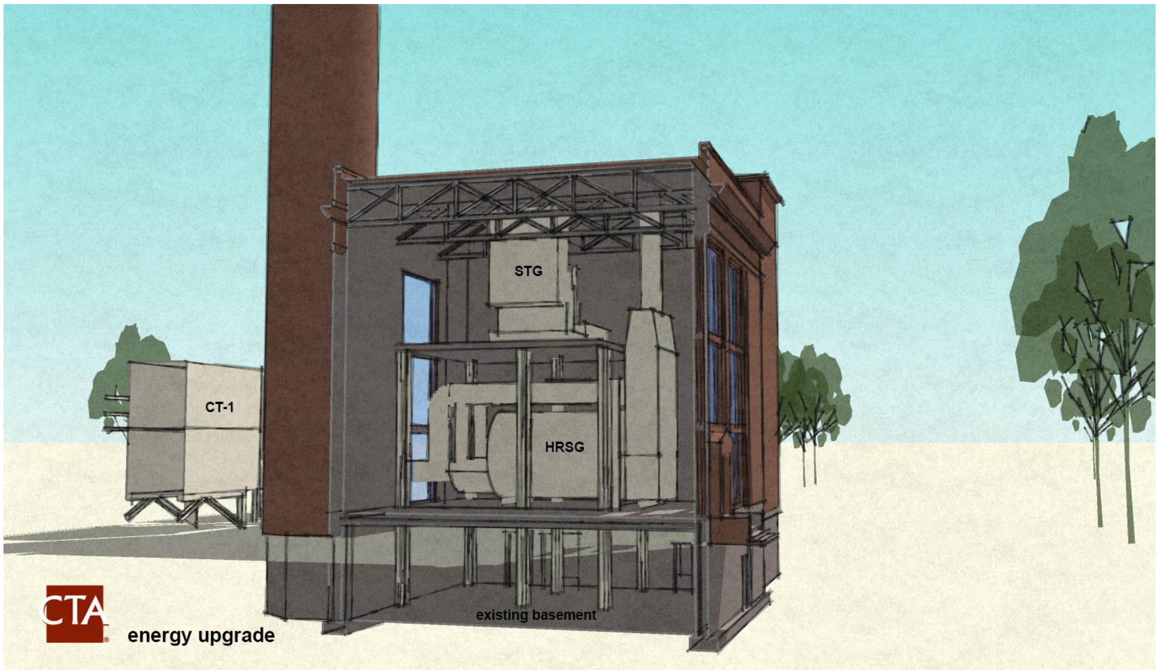
Campus electric load is the actual demand minus the steam turbine output in this graph.





Annual average unfired steam flow from the OPRA16 turbines is approximately 27,000 lb/hr.





General Arrangement of Equipment

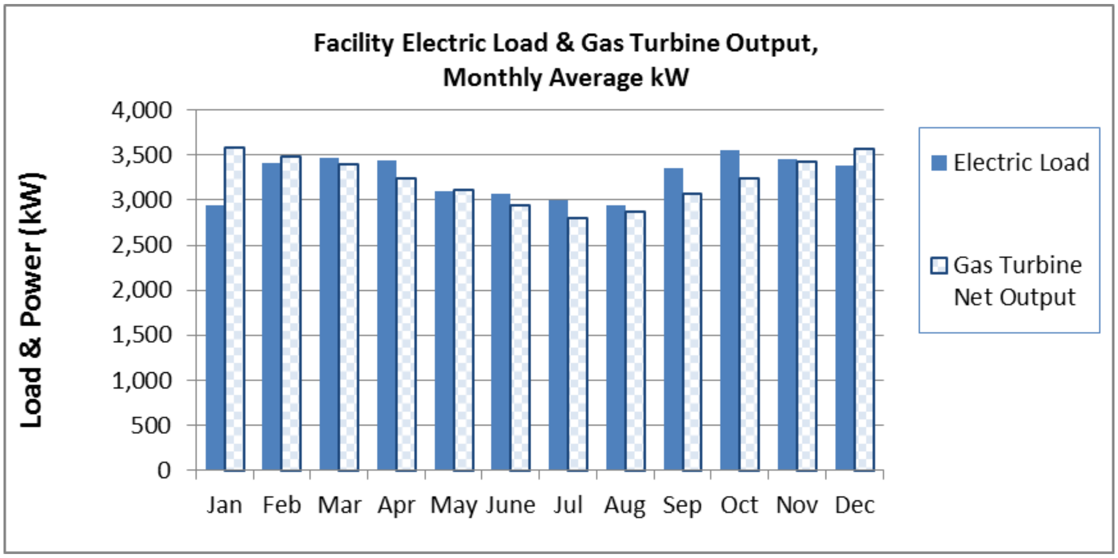
A section through the boiler plant shows the general arrangement of the CHP plant with the turbines supported on helical piers and steel framing; the new Heat Recovery Steam Generator (HRSG) located in place of the current boiler, B-3; and the steam turbine generator located above on a new platform, or mezzanine level.

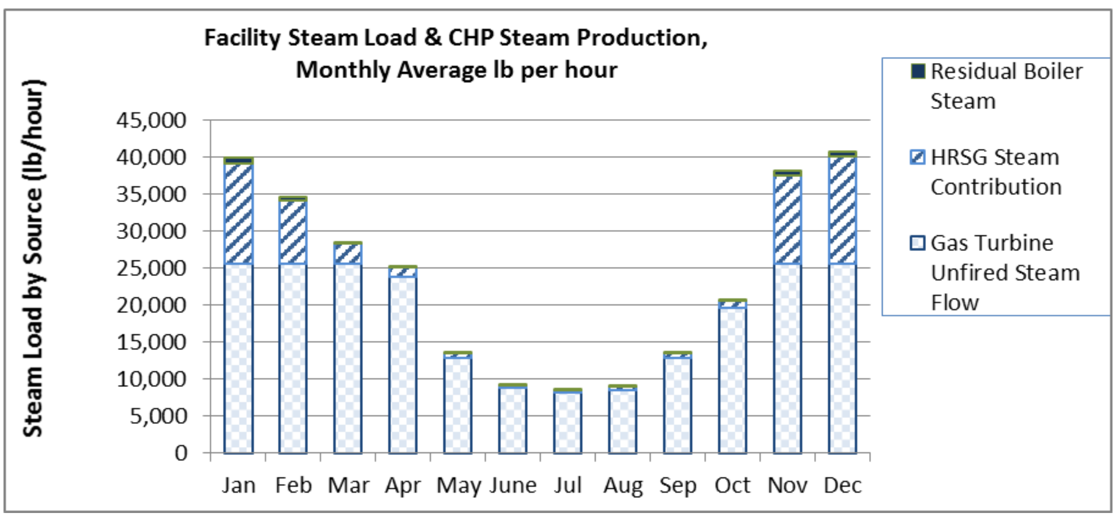
B. OPRA Turbines with "Sales"

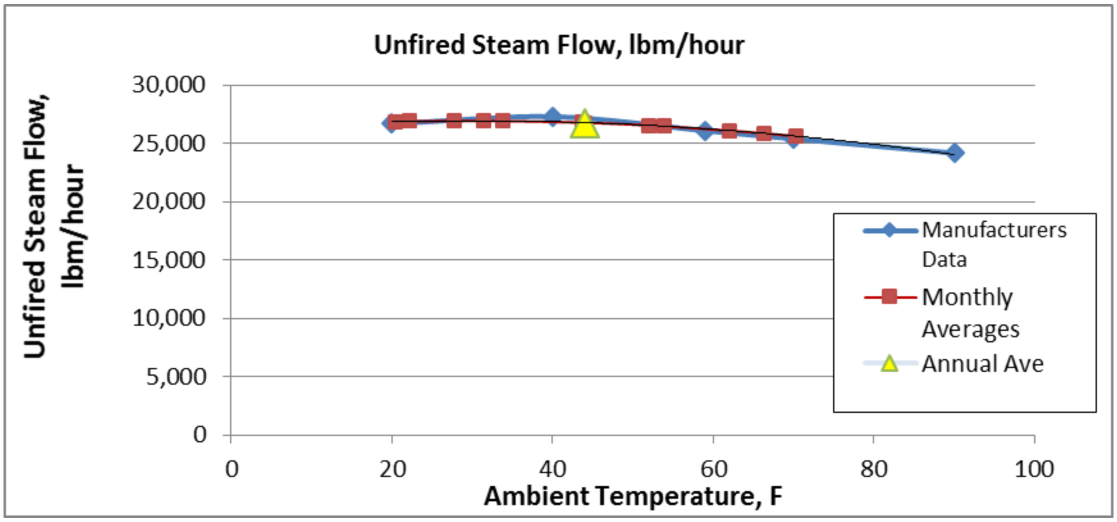
Same as option A. above, except excess electric is purchased by Northwestern Energy at $0.055/kWh. Simple payback is 7.9 years and overall CHP efficiency is 64%. The efficiency figure does not include the heat recovery of the economizer unit, which should get the overall efficiency to 65%. Electric demand savings are $382,072/yr.

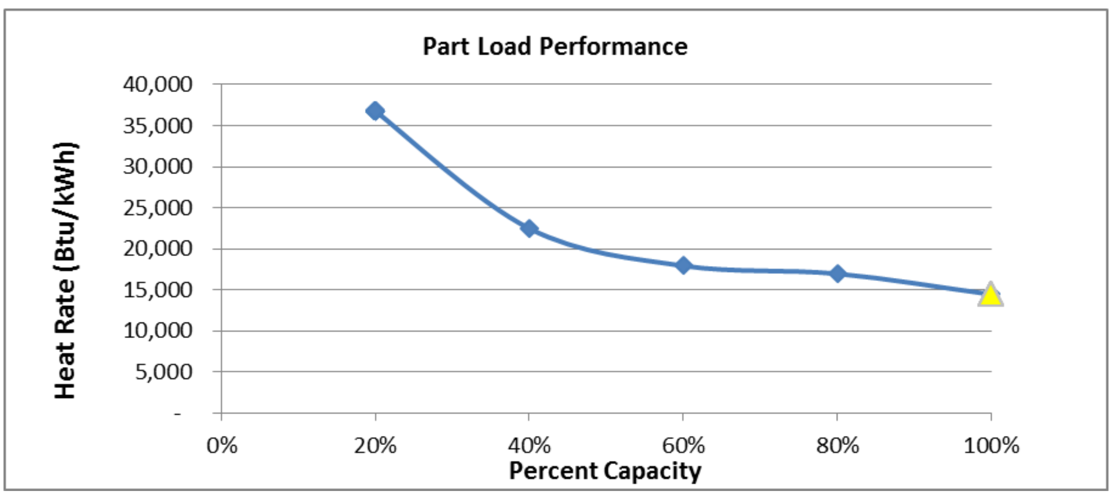
ENERGY ANALYSIS SUMMARY		
Plant Loads		
Average Plant Electricity Load, Avg kW	4,107	kW Avg
Average Plant Thermal Load, MMBtu/h	23.0	MMBtu/h
Displaced Thermal Efficiency	84.0%	
Baseline Energy Use & Costs	**Energy Use**	**Cost**
Baseline Electricity Energy Use, kWh/year, and Cost, $/year	35,961,680	$2,741,247
Baseline Electricity Demand Cost, $/year		$648,861
Baseline Fuel Use, MMBtu/year, and Cost, $/year	239,043	$1,135,474
CHP Alternative Energy Use & Costs	**Energy**	**Cost**
CHP Electricity Generated, kWh/year	34,427,805	
CHP Electricity Energy Purchased, kWh/year	2,444,271	$186,287
Demand Charges Not Offset by CHP, $		$266,789
CHP Electricity Sales, kWh/year	910,396	$50,072
CHP Fuel Used, MMBtu/year	418,349	$1,987,158
HRSG Fuel Used, MMBtu/year	52,230	$248,095
Residual Boiler Fuel to Serve Thermal Needs Not Met by CHP, MMBtu/year, and Cost, $/year	2,287	$10,862
Incremental O&M Cost, $/year		$289,142
System Performance		
Average Heat Rate, Btu/kWh, with parasitic loads at ambient temperature, elevation, part load	12,151	Btu/kWh
Fuel Rate at Full Fire, MMBtu/h	50.28	MMBtu/h
Fuel Rate at Part Load, MMBtu/h	50.28	MMBtu/h
Average CHP Thermal Output	24.76	MMBtu/h
CHP Thermal Output per kWh	8,079	Btu/kWh
Annual Heat Recoverd By CHP (MMBtu/year)	159,149	MMBtu/year
Average Electrical Efficiency, Btu/kWh, with parasitic loads at temperature, elevation, part load	28.1%	
Average Thermal Efficiency	35.7%	
Average CHP Thermal Efficiency	63.8%	
Fuel Chargeable to Power Heat Rate (Btu/kWh)	7,127	Btu/kWh
CHP System Operation		
Availability	95.0%	
Average Operation as Percent of Capacity (Capacity Factor)	100.0%	
Plant Electricity Needs Met by CHP	93.2%	
Plant Thermal Needs Met by CHP	85.2%	
Payback		
Total Installed Cost	$12,090,000	
Avoided Costs	$0	
Grants	$0	
Annual O&M Costs	$289,142	
Energy Cost Savings	$1,770,185	
Sales Revenue	$50,072	
Total Operating Savings	$1,531,115	
Payback Before Incentives (years)	7.90	years
Payback with Incentives (years)	7.90	years

Efficiencies	CHP Annual
Electrical Efficiency at Part-Load, Mean Monthly Temperature after Auxiliary Loads	28%
Thermal Efficiency	36%
Overall Efficiency	64%
Heat Rate, Btu/kWh	12,151


Facility Electric Load & Gas Turbine Output, Monthly Average kW
Load & Power (kW)
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Jan
Feb
Mar
Apr
May
June
Jul
Aug
Sep
Oct
Nov
Dec
Electric Load
Gas Turbine Net Output


Facility Steam Load & CHP Steam Production, Monthly Average lb per hour
Steam Load by Source (lb/hour)
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Jan
Feb
Mar
Apr
May
June
Jul
Aug
Sep
Oct
Nov
Dec
Residual Boiler Steam
HRSG Steam Contribution
Gas Turbine Unfired Steam Flow





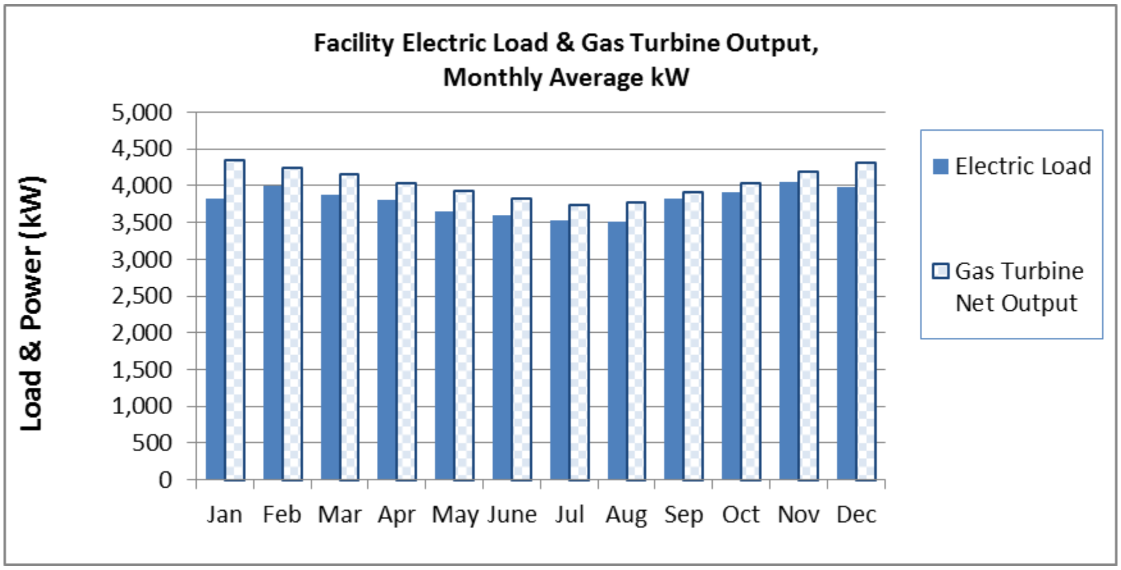
The “Sales” scenario shows the turbines running at 100% throughout the year.

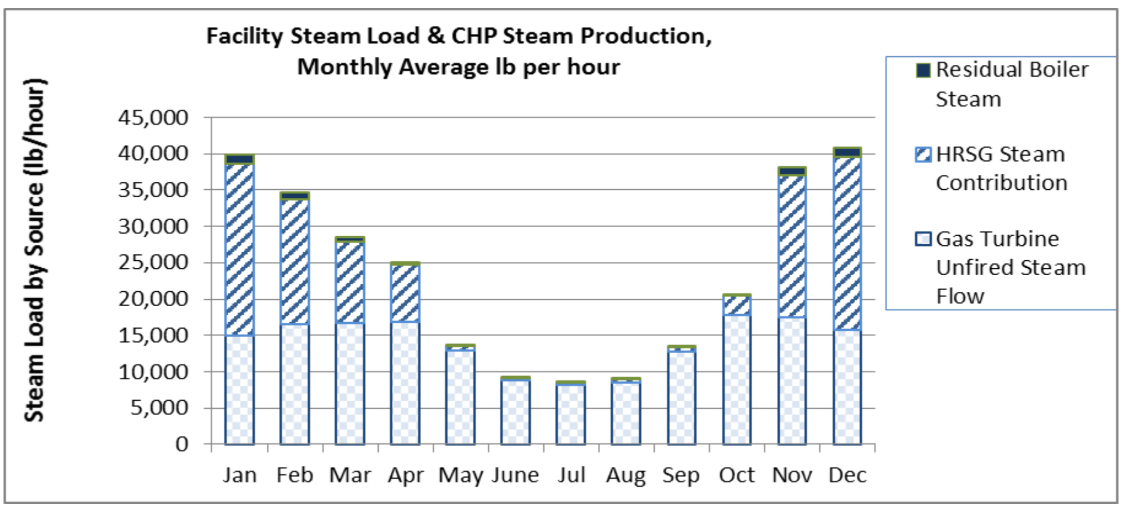
C. Solar Centaur 50 Turbine "No Sales"

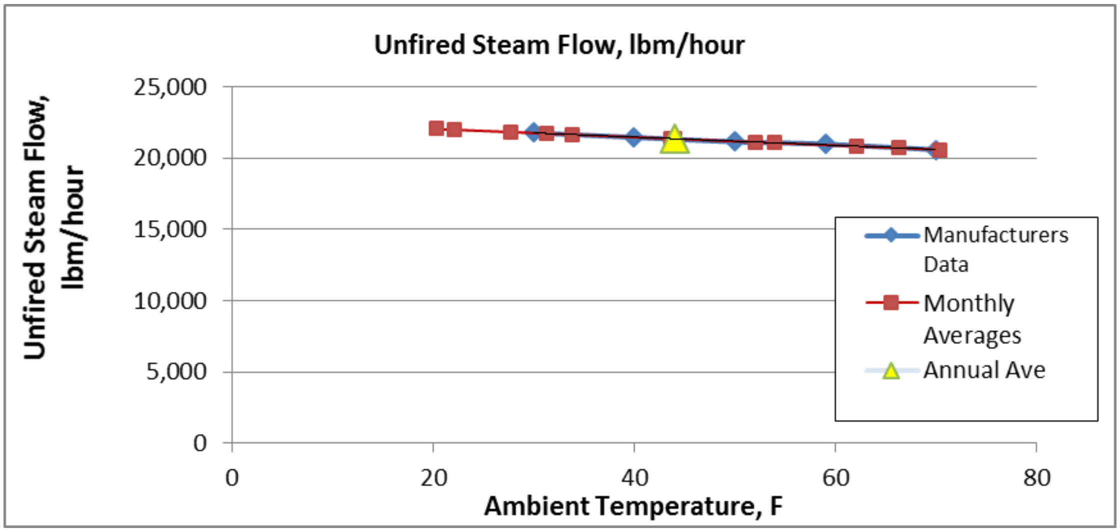
A single Centaur 50 turbine with watertube HRSG and dual pressure STG. Auxiliary equipment includes a surface condenser and cooling tower. Simple payback is 12.7 years and overall CHP efficiency is 53%. Electric demand savings are $314,219/yr.

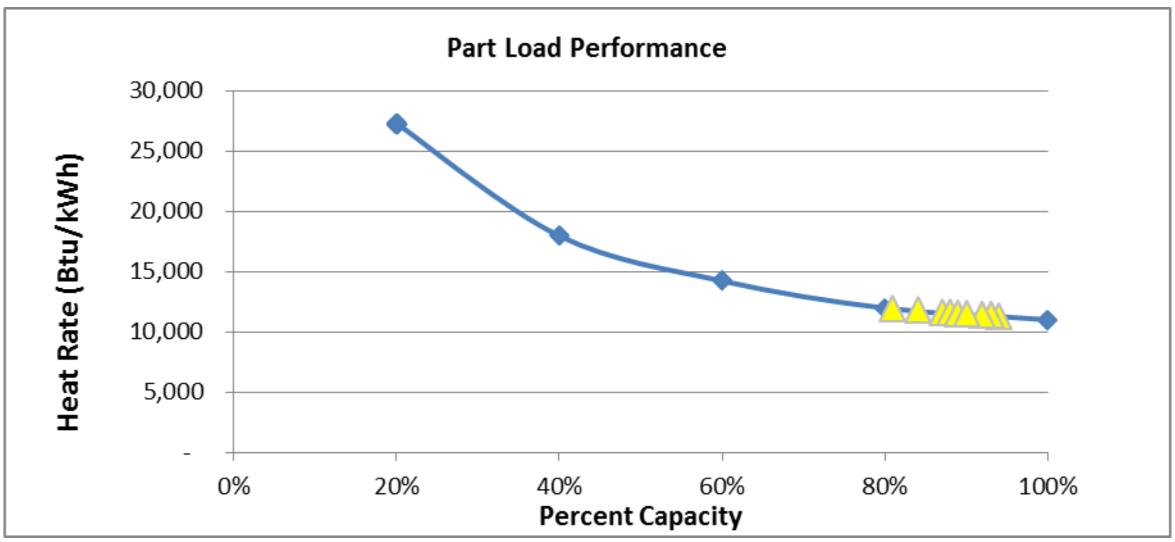
ENERGY ANALYSIS SUMMARY		
Plant Loads		
Average Plant Electricity Load, Avg kW	4,107	kW Avg
Average Plant Thermal Load, MMBtu/h	23.0	MMBtu/h
Displaced Thermal Efficiency	84.0%	
Baseline Energy Use & Costs	**Energy Use**	**Cost**
Baseline Electricity Energy Use, kWh/year, and Cost, $/year	35,961,680	$2,741,247
Baseline Electricity Demand Cost, $/year		$648,861
Baseline Fuel Use, MMBtu/year, and Cost, $/year	239,043	$1,135,474
CHP Alternative Energy Use & Costs	**Energy**	**Cost**
CHP Electricity Generated, kWh/year	32,679,958	
CHP Electricity Energy Purchased, kWh/year	3,283,811	$250,264
Demand Charges Not Offset by CHP, $		$334,641
CHP Electricity Sales, kWh/year	0	$0
CHP Fuel Used, MMBtu/year	420,171	$1,995,814
HRSG Fuel Used, MMBtu/year	101,012	$479,805
Residual Boiler Fuel to Serve Thermal Needs Not Met by CHP, MMBtu/year, and Cost, $/year	4,422	$21,006
Incremental O&M Cost, $/year		$369,275
System Performance		
Average Heat Rate, Btu/kWh, with parasitic loads at ambient temperature, elevation, part load	14,011	Btu/kWh
Fuel Rate at Full Fire, MMBtu/h	54.10	MMBtu/h
Fuel Rate at Part Load, MMBtu/h	50.50	MMBtu/h
Average CHP Thermal Output	17.76	MMBtu/h
CHP Thermal Output per kWh	5,189	Btu/kWh
Annual Heat Recoverd By CHP (MMBtu/year)	119,619	MMBtu/year
Average Electrical Efficiency, Btu/kWh, with parasitic loads at temperature, elevation, part load	26.5%	
Average Thermal Efficiency	26.9%	
Average CHP Thermal Efficiency	53.5%	
Fuel Chargeable to Power Heat Rate (Btu/kWh)	8,879	Btu/kWh
CHP System Operation		
Availability	95.0%	
Average Operation as Percent of Capacity (Capacity Factor)	89.3%	
Plant Electricity Needs Met by CHP	90.9%	
Plant Thermal Needs Met by CHP	71.4%	
Payback		
Total Installed Cost	$12,950,000	
Avoided Costs	$0	
Grants	$0	
Annual O&M Costs	$369,275	
Energy Cost Savings	$1,392,315	
Sales Revenue	$0	
Total Operating Savings	$1,023,041	
Payback Before Incentives (years)	12.66	years
Payback with Incentives (years)	12.66	years

Efficiencies	CHP Annual
Electrical Efficiency at Part-Load, Mean Monthly Temperature after Auxiliary Loads	27%
Thermal Efficiency	27%
Overall Efficiency	53%
Heat Rate, Btu/kWh	14,011


Facility Electric Load & Gas Turbine Output,
Monthly Average kW
Load & Power (kW)
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Jan Feb Mar Apr May June Jul Aug Sep Oct Nov Dec
Electric Load
Gas Turbine Net Output


Facility Steam Load & CHP Steam Production,
Monthly Average lb per hour
Steam Load by Source (lb/hour)
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Jan Feb Mar Apr May June Jul Aug Sep Oct Nov Dec
Residual Boiler Steam
HRSG Steam Contribution
Gas Turbine Unfired Steam Flow





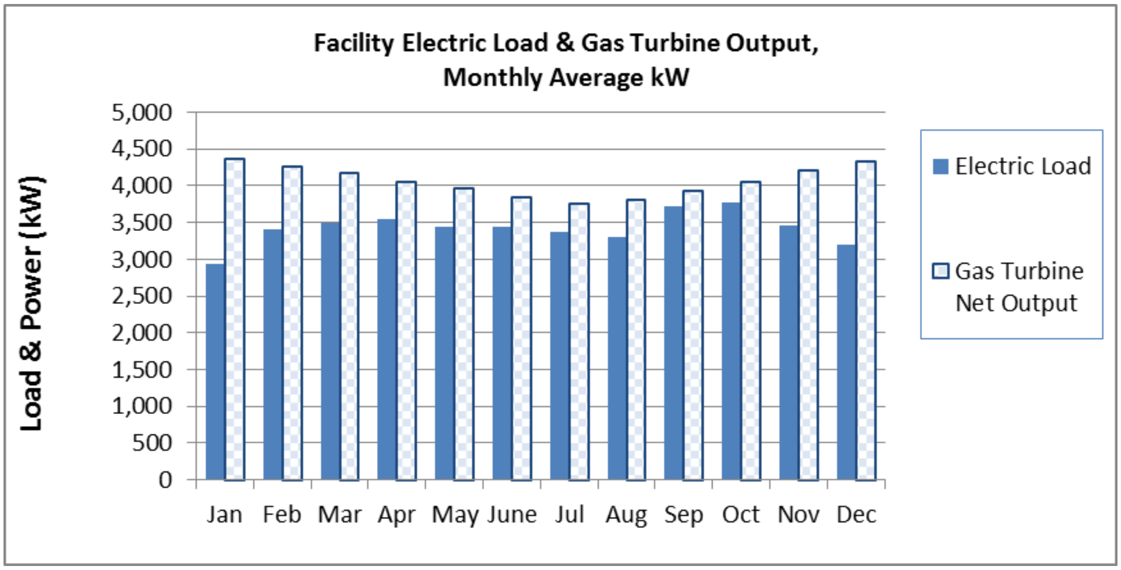
Note the wider variation in capacity throughout the year due to excess capacity.

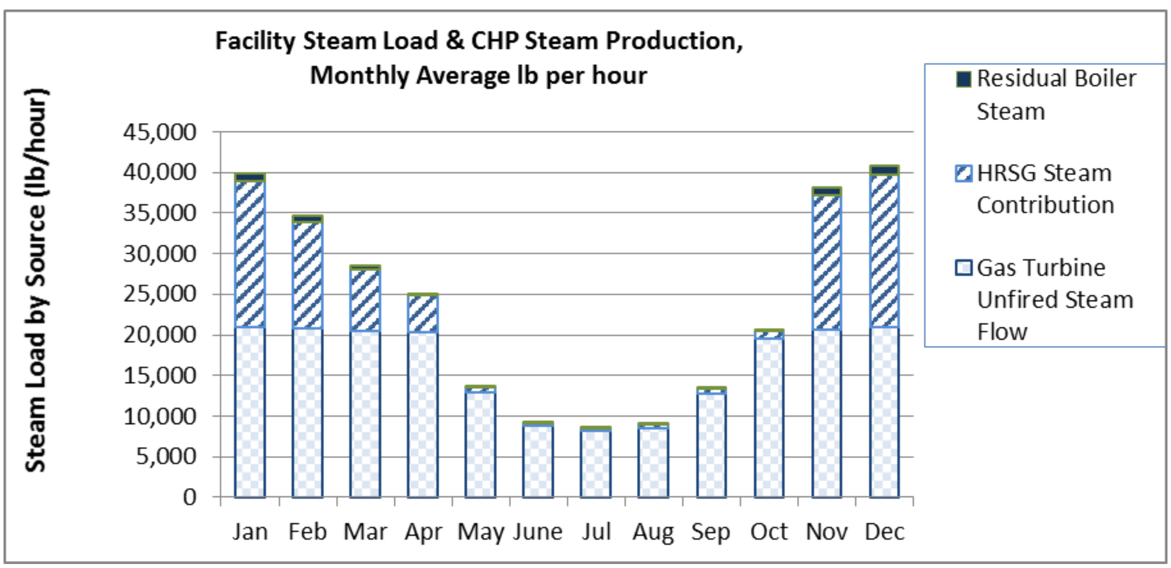
D. Solar Centaur 50 Turbine with "Sales"

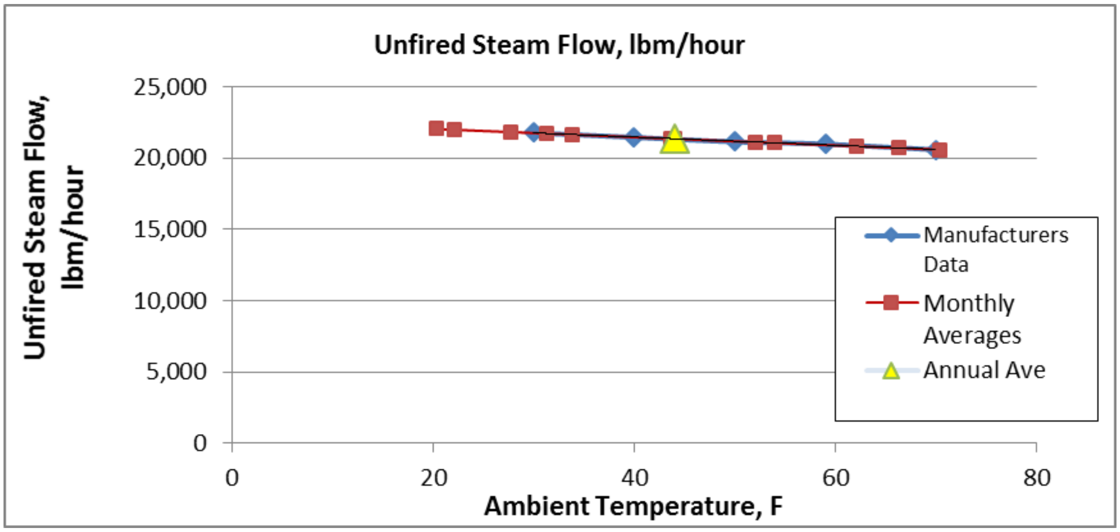
Same as option C. above except excess electrical power is purchased by Northwestern Energy at $0.055/kWh. Simple payback is 9.2 years and overall CHP efficiency is 59%. Electric demand savings are $380,958/yr.

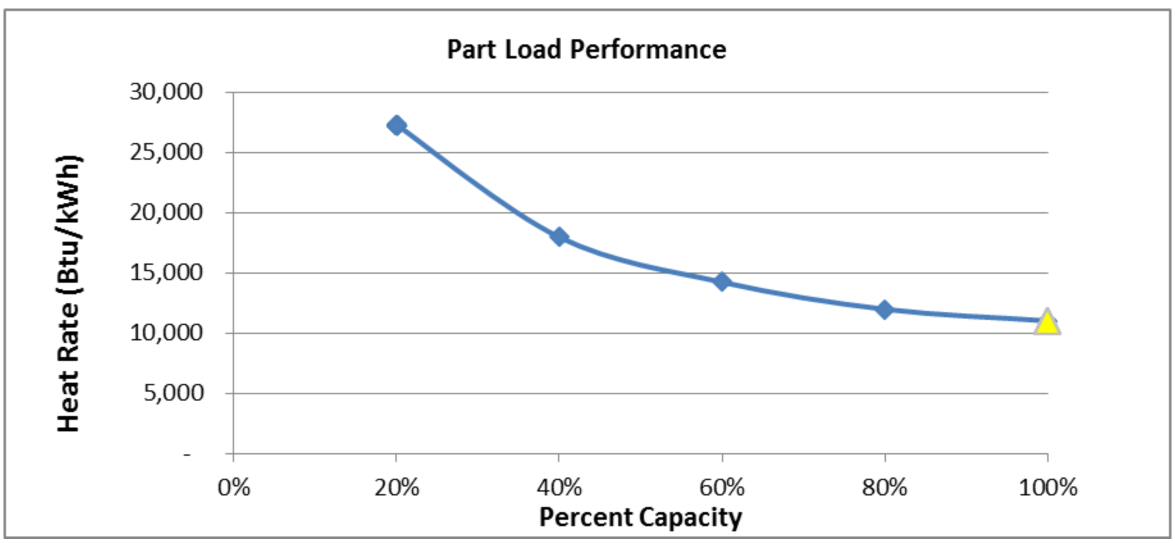
ENERGY ANALYSIS SUMMARY		
Plant Loads		
Average Plant Electricity Load, Avg kW	4,107	kW Avg
Average Plant Thermal Load, MMBtu/h	23.0	MMBtu/h
Displaced Thermal Efficiency	84.0%	
Baseline Energy Use & Costs	**Energy Use**	**Cost**
Baseline Electricity Energy Use, kWh/year, and Cost, $/year	35,961,680	$2,741,247
Baseline Electricity Demand Cost, $/year		$648,861
Baseline Fuel Use, MMBtu/year, and Cost, $/year	239,043	$1,135,474
CHP Alternative Energy Use & Costs	**Energy**	**Cost**
CHP Electricity Generated, kWh/year	39,755,387	
CHP Electricity Energy Purchased, kWh/year	1,798,084	$137,156
Demand Charges Not Offset by CHP, $		$267,902
CHP Electricity Sales, kWh/year	5,591,791	$307,549
CHP Fuel Used, MMBtu/year	450,087	$2,137,915
HRSG Fuel Used, MMBtu/year	76,636	$364,021
Residual Boiler Fuel to Serve Thermal Needs Not Met by CHP, MMBtu/year, and Cost, $/year	3,355	$15,937
Incremental O&M Cost, $/year		$392,619
System Performance		
Average Heat Rate, Btu/kWh, with parasitic loads at ambient temperature, elevation, part load	13,318	Btu/kWh
Fuel Rate at Full Fire, MMBtu/h	54.10	MMBtu/h
Fuel Rate at Part Load, MMBtu/h	54.10	MMBtu/h
Average CHP Thermal Output	19.90	MMBtu/h
CHP Thermal Output per kWh	5,158	Btu/kWh
Annual Heat Recoverd By CHP (MMBtu/year)	139,325	MMBtu/year
Average Electrical Efficiency, Btu/kWh, with parasitic loads at temperature, elevation, part load	30.1%	
Average Thermal Efficiency	29.1%	
Average CHP Thermal Efficiency	59.2%	
Fuel Chargeable to Power Heat Rate (Btu/kWh)	7,512	Btu/kWh
CHP System Operation		
Availability	95.0%	
Average Operation as Percent of Capacity (Capacity Factor)	100.0%	
Plant Electricity Needs Met by CHP	95.0%	
Plant Thermal Needs Met by CHP	78.4%	
Payback		
Total Installed Cost	$12,950,000	
Avoided Costs	$0	
Grants	$0	
Annual O&M Costs	$392,619	
Energy Cost Savings	$1,546,253	
Sales Revenue	$307,549	
Total Operating Savings	$1,461,183	
Payback Before Incentives (years)	8.86	years
Payback with Incentives (years)	8.86	years

Efficiencies	CHP Annual
Electrical Efficiency at Part-Load, Mean Monthly Temperature after Auxiliary Loads	30%
Thermal Efficiency	29%
Overall Efficiency	59%
Heat Rate, Btu/kWh	13,318


Facility Electric Load & Gas Turbine Output,
Monthly Average kW
Load & Power (kW)
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Jan Feb Mar Apr May June Jul Aug Sep Oct Nov Dec
Electric Load
Gas Turbine Net Output


Facility Steam Load & CHP Steam Production,
Monthly Average lb per hour
Steam Load by Source (lb/hour)
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Jan Feb Mar Apr May June Jul Aug Sep Oct Nov Dec
Residual Boiler Steam
HRSG Steam Contribution
Gas Turbine Unfired Steam Flow


Unfired Steam Flow, lbm/hour
Unfired Steam Flow, lbm/hour
25,000
20,000
15,000
10,000
5,000
0
0
20
40
60
80
Ambient Temperature, F
Manufacturers Data
Monthly Averages
Annual Ave

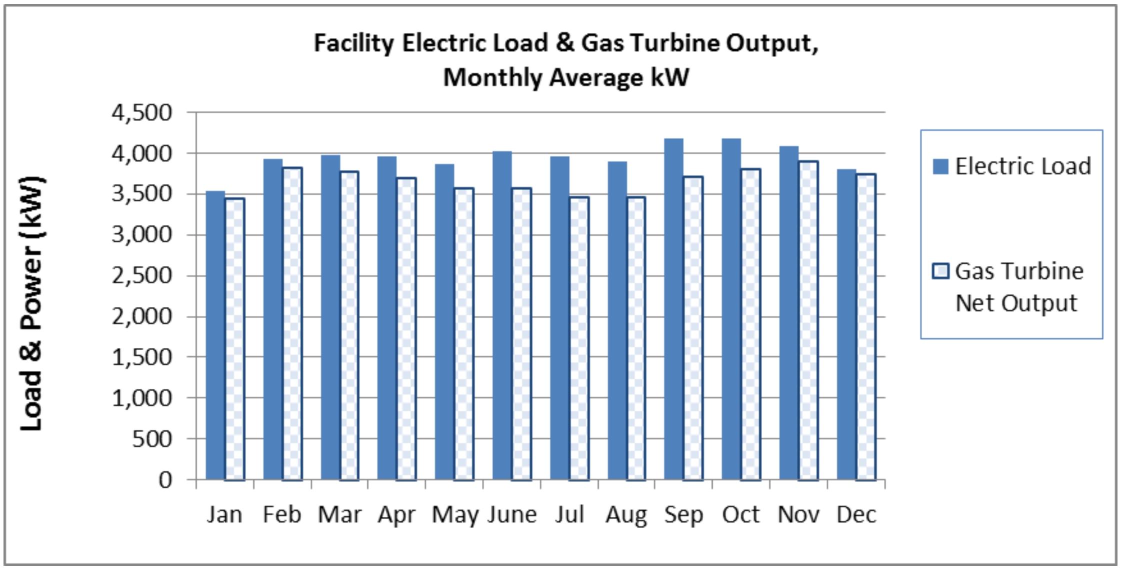

Part Load Performance
Heat Rate (Btu/kWh)
30,000
25,000
20,000
15,000
10,000
5,000
-
0%
20%
40%
60%
80%
100%
Percent Capacity

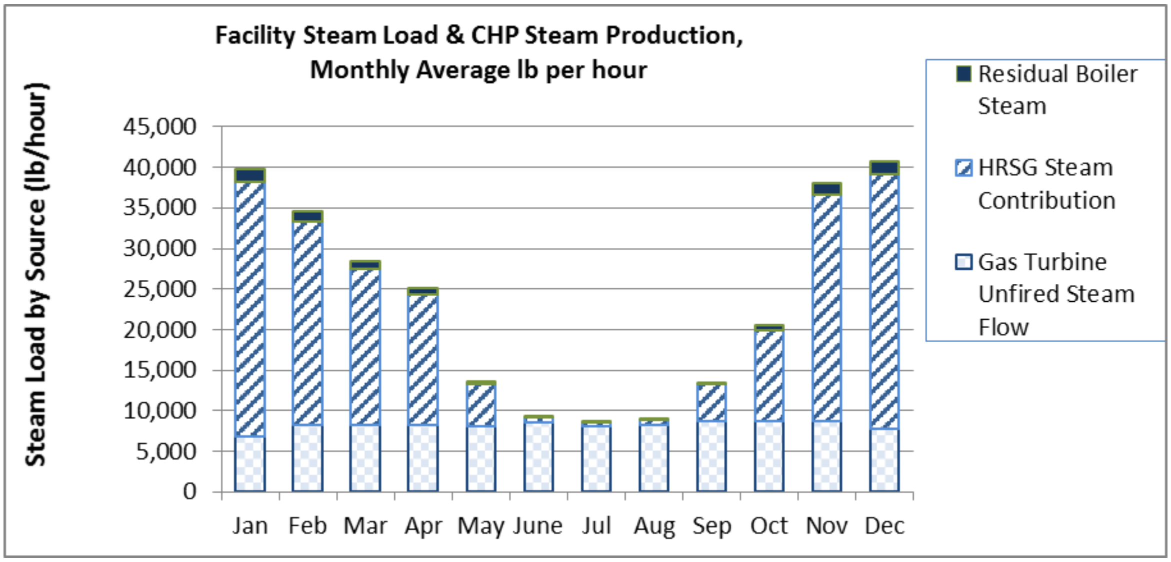
E. Solar Mercury 50 "No Sales"

Mercury 50 turbine with no electrical sales and watertube HRSG. Simple payback is 16.2 years and overall CHP efficiency is 53%. Electric demand savings are $294,600/yr.

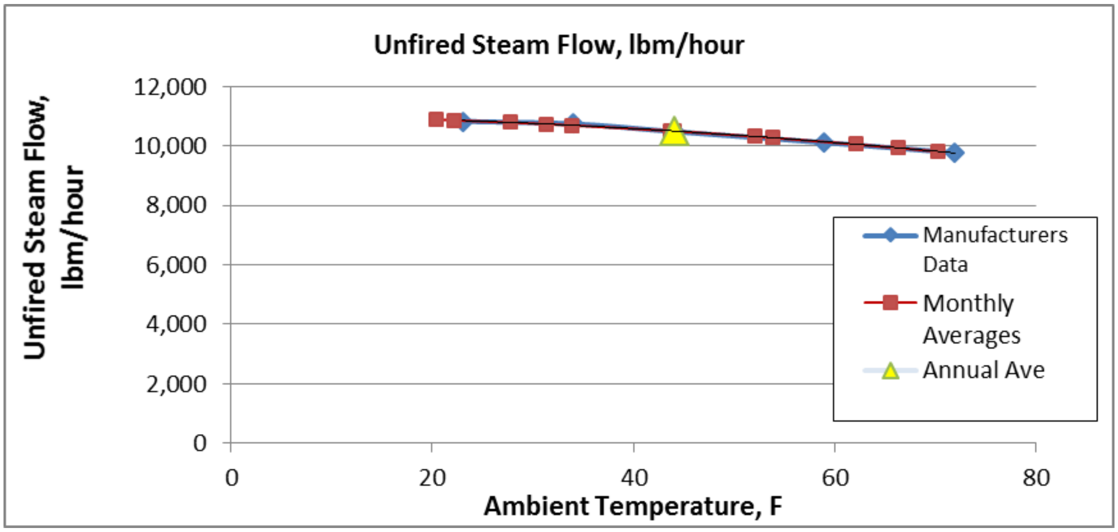
ENERGY ANALYSIS SUMMARY		
Plant Loads		
Average Plant Electricity Load, Avg kW	3,950	kW Avg
Average Plant Thermal Load, MMBtu/h	23.0	MMBtu/h
Displaced Thermal Efficiency	84.0%	
Baseline Energy Use & Costs	**Energy Use**	**Cost**
Baseline Electricity Energy Use, kWh/year, and Cost, $/year	34,593,944	$2,620,207
Baseline Electricity Demand Cost, $/year		$640,802
Baseline Fuel Use, MMBtu/year, and Cost, $/year	239,043	$1,135,474
CHP Alternative Energy Use & Costs	**Energy**	**Cost**
CHP Electricity Generated, kWh/year	30,506,389	
CHP Electricity Energy Purchased, kWh/year	4,087,556	$310,086
Demand Charges Not Offset by CHP, $		$346,202
CHP Electricity Sales, kWh/year	0	$0
CHP Fuel Used, MMBtu/year	320,898	$1,524,268
HRSG Fuel Used, MMBtu/year	161,674	$767,951
Residual Boiler Fuel to Serve Thermal Needs Not Met by CHP, MMBtu/year, and Cost, $/year	7,078	$33,621
Incremental O&M Cost, $/year		$655,887
System Performance		
Average Heat Rate, Btu/kWh, with parasitic loads at ambient temperature, elevation, part load	10,519	Btu/kWh
Fuel Rate at Full Fire, MMBtu/h	41.38	MMBtu/h
Fuel Rate at Part Load, MMBtu/h	38.57	MMBtu/h
Average CHP Thermal Output	8.66	MMBtu/h
CHP Thermal Output per kWh	2,487	Btu/kWh
Annual Heat Recoverd By CHP (MMBtu/year)	70,590	MMBtu/year
Average Electrical Efficiency, Btu/kWh, with parasitic loads at temperature, elevation, part load	32.4%	
Average Thermal Efficiency	20.9%	
Average CHP Thermal Efficiency	53.3%	
Fuel Chargeable to Power Heat Rate (Btu/kWh)	8,004	Btu/kWh
CHP System Operation		
Availability	95.0%	
Average Operation as Percent of Capacity (Capacity Factor)	89.0%	
Plant Electricity Needs Met by CHP	88.2%	
Plant Thermal Needs Met by CHP	49.4%	
Payback		
Total Installed Cost	$11,758,000	
Avoided Costs	$0	
Grants	$0	
Annual O&M Costs	$655,887	
Energy Cost Savings	$1,380,504	
Sales Revenue	$0	
Total Operating Savings	$724,616	
Payback Before Incentives (years)	16.23	years
Payback with Incentives (years)	16.23	years

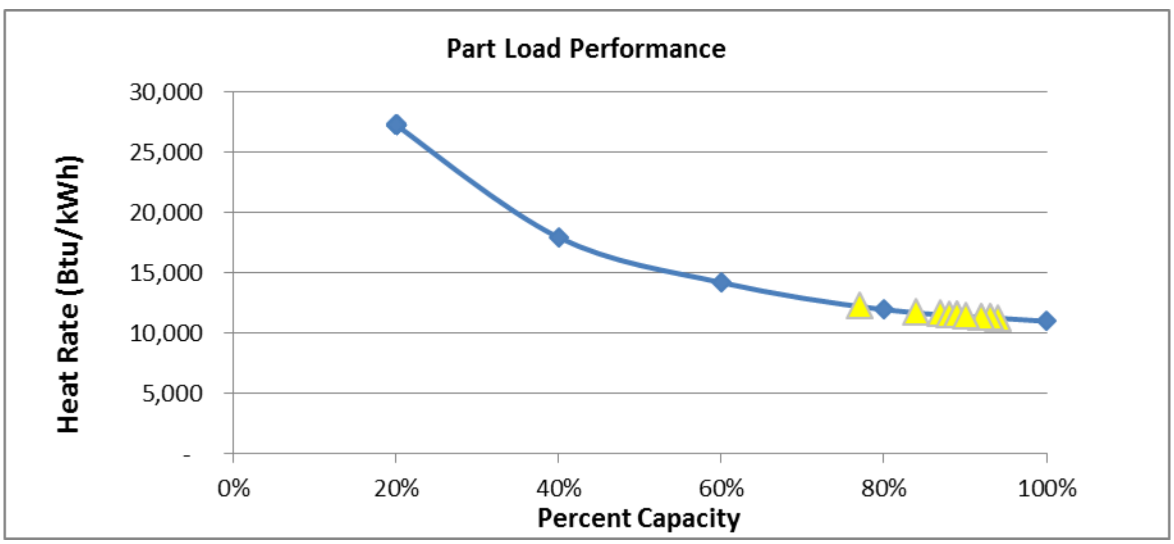
Efficiencies	CHP Annual
Electrical Efficiency at Part-Load, Mean Monthly Temperature after Auxiliary Loads	32%
Thermal Efficiency	21%
Overall Efficiency	53%
Heat Rate, Btu/kWh	10,519





The Mercury 50 turbine has a lower unfired steam output, therefore, the HRSG utilizes supplemental firing to meet a majority of the steam load.


Unfired Steam Flow, lbm/hour
Unfired Steam Flow, lbm/hour
12,000
10,000
8,000
6,000
4,000
2,000
0
0
20
40
60
80
Ambient Temperature, F
Manufacturers Data
Monthly Averages
Annual Ave

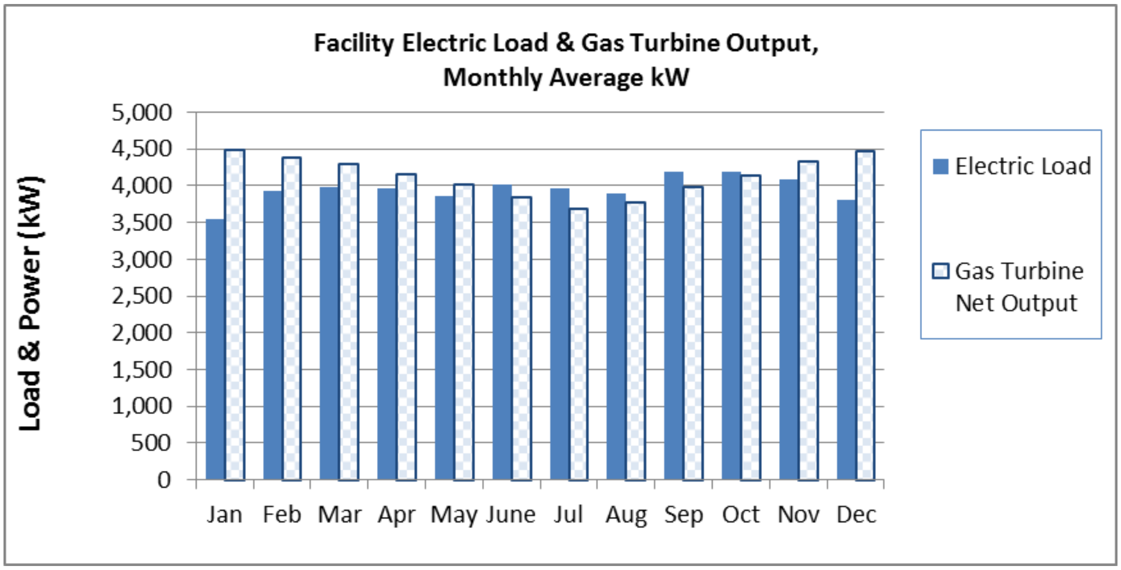

Part Load Performance
Heat Rate (Btu/kWh)
30,000
25,000
20,000
15,000
10,000
5,000
-
0%
20%
40%
60%
80%
100%
Percent Capacity

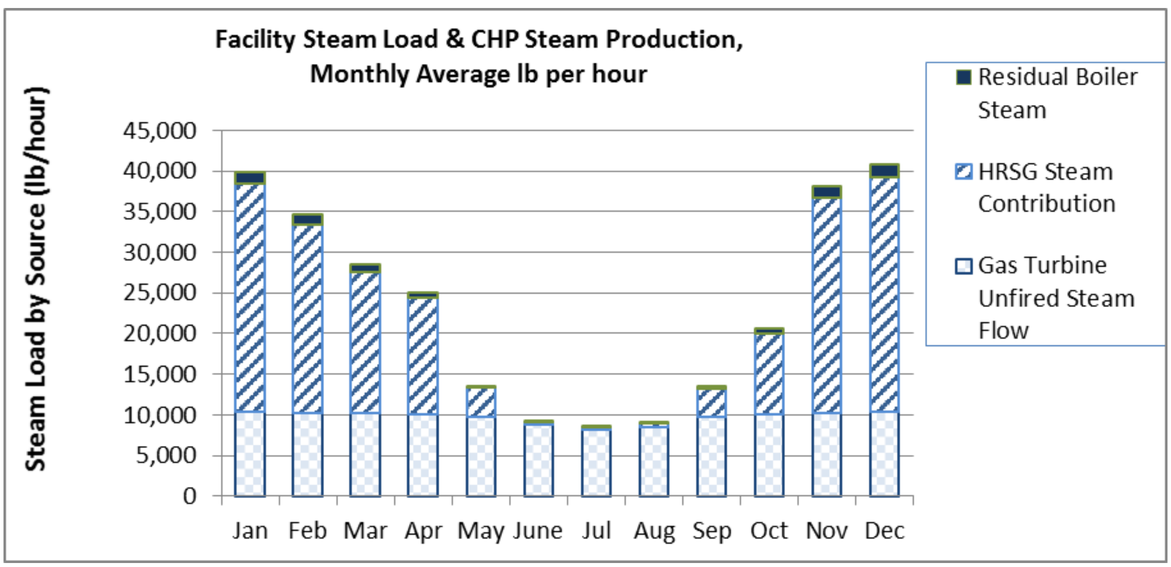
F. Solar Mercury 50 Turbine with "Sales"

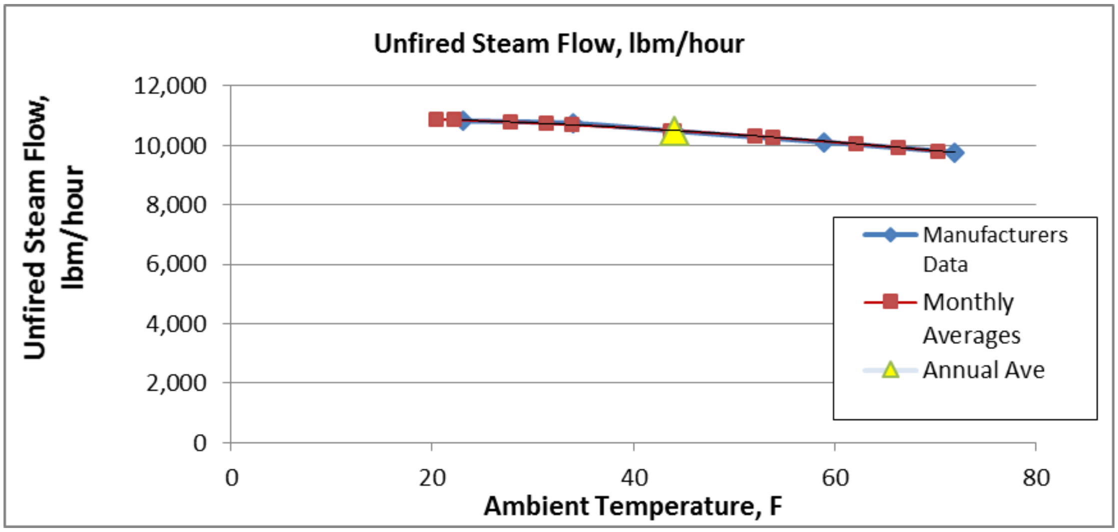
Same as option E. above except excess electric power is purchased by Northwestern Energy at $0.055/kWh. Simple payback is 11.9 years and overall CHO efficiency is 57%. Electric demand savings are $331,892/yr.

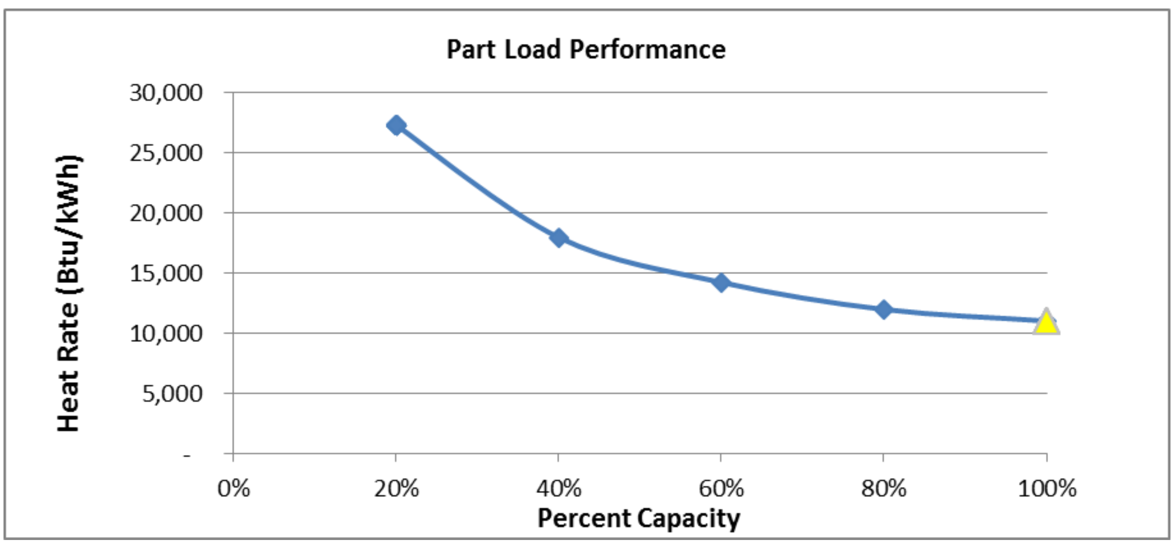
ENERGY ANALYSIS SUMMARY		
Plant Loads		
Average Plant Electricity Load, Avg kW	3,950	kW Avg
Average Plant Thermal Load, MMBtu/h	23.0	MMBtu/h
Displaced Thermal Efficiency	84.0%	
Baseline Energy Use & Costs	**Energy Use**	**Cost**
Baseline Electricity Energy Use, kWh/year, and Cost, $/year	34,593,944	$2,620,207
Baseline Electricity Demand Cost, $/year		$640,802
Baseline Fuel Use, MMBtu/year, and Cost, $/year	239,043	$1,135,474
CHP Alternative Energy Use & Costs	**Energy**	**Cost**
CHP Electricity Generated, kWh/year	34,370,243	
CHP Electricity Energy Purchased, kWh/year	2,297,817	$174,221
Demand Charges Not Offset by CHP, $		$308,910
CHP Electricity Sales, kWh/year	2,074,115	$114,076
CHP Fuel Used, MMBtu/year	344,243	$1,635,156
HRSG Fuel Used, MMBtu/year	146,053	$693,750
Residual Boiler Fuel to Serve Thermal Needs Not Met by CHP, MMBtu/year, and Cost, $/year	6,394	$30,372
Incremental O&M Cost, $/year		$651,316
System Performance		
Average Heat Rate, Btu/kWh, with parasitic loads at ambient temperature, elevation, part load	10,016	Btu/kWh
Fuel Rate at Full Fire, MMBtu/h	41.38	MMBtu/h
Fuel Rate at Part Load, MMBtu/h	41.38	MMBtu/h
Average CHP Thermal Output	9.74	MMBtu/h
CHP Thermal Output per kWh	2,483	Btu/kWh
Annual Heat Recoverd By CHP (MMBtu/year)	83,184	MMBtu/year
Average Electrical Efficiency, Btu/kWh, with parasitic loads at temperature, elevation, part load	34.0%	
Average Thermal Efficiency	22.9%	
Average CHP Thermal Efficiency	57.0%	
Fuel Chargeable to Power Heat Rate (Btu/kWh)	7,385	Btu/kWh
CHP System Operation		
Availability	95.0%	
Average Operation as Percent of Capacity (Capacity Factor)	100.0%	
Plant Electricity Needs Met by CHP	93.4%	
Plant Thermal Needs Met by CHP	55.1%	
Payback		
Total Installed Cost	$11,758,000	
Avoided Costs	$0	
Grants	$0	
Annual O&M Costs	$651,316	
Energy Cost Savings	$1,518,475	
Sales Revenue	$114,076	
Total Operating Savings	$981,235	
Payback Before Incentives (years)	11.98	years
Payback with Incentives (years)	11.98	years

Efficiencies	CHP Annual
Electrical Efficiency at Part-Load, Mean Monthly Temperature after Auxiliary Loads	34%
Thermal Efficiency	23%
Overall Efficiency	57%
Heat Rate, Btu/kWh	10,016


Facility Electric Load & Gas Turbine Output,
Monthly Average kW
Load & Power (kW)
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Jan Feb Mar Apr May June Jul Aug Sep Oct Nov Dec
Electric Load
Gas Turbine Net Output


Facility Steam Load & CHP Steam Production,
Monthly Average lb per hour
Steam Load by Source (lb/hour)
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Jan Feb Mar Apr May June Jul Aug Sep Oct Nov Dec
Residual Boiler Steam
HRSG Steam Contribution
Gas Turbine Unfired Steam Flow


Unfired Steam Flow, lbm/hour
Unfired Steam Flow, lbm/hour
12,000
10,000
8,000
6,000
4,000
2,000
0
0
20
40
60
80
Ambient Temperature, F
Manufacturers Data
Monthly Averages
Annual Ave


Part Load Performance
Heat Rate (Btu/kWh)
30,000
25,000
20,000
15,000
10,000
5,000
-
0%
20%
40%
60%
80%
100%
Percent Capacity

CHP Mechanical Integration

Existing Central Boiler Plant

The central boiler plant provides 30 psi steam to the campus to satisfy the space heating demand. There are three boilers:

- B-1: Keeler watertube boiler rated at 200 psi and 70,000 pph saturated steam fired with natural gas. The combustion vent currently terminates at a roof-mounted hood.
- B-2: Babcock and Wilcox watertube boiler rated at 225 psi and 30,000 pph saturated steam fired with natural gas. Currently this boiler will only produce 25,000 pph saturated steam after a variable speed drive retrofit to the FD fan. The combustion vent for this boiler terminates in the original 150' stack.
- B-3: Keeler watertube boiler rated at 200 psi and 70,000 pph saturated steam. This boiler is configured to burn both natural gas and no. 2 fuel oil. The combustion vent currently terminates at a roof-mounted hood.

The steam pressure is controlled at the boiler plant to 180 psi, but is distributed to the campus at 30 psi. In addition to a pressure-reducing valve assembly, a 440 kW steam turbine was installed in the 1990's to generate electric power while reducing the steam pressure to 30 psi. The maximum steam flow rate through this turbine is approximately 30,000 pph. As the campus heating steam demand rises above this level, additional steam is provided to the campus via the pressure-reducing valve assembly.

Natural Gas Service

The existing natural gas service to the boiler plant is 75 psi. The proposed CHP unit will be a natural gas fired combustion turbine which will require a natural gas supply pressure of approximately 200 psi. A compressor unit can be installed on site to provide the necessary pressure; the installed cost of this unit is estimated to be $600,000 to $700,000 and would add a 75 kW parasitic electric load resulting in an additional operating cost in excess of $50,000 per year.

Discussions with Northwestern Energy verified that the existing gas service has adequate capacity to handle a 4-5 MW turbine. Additionally, the pressure on the intermediate gas supply main to the boiler plant can be raised to the required 200 psi pressure by reconfiguration of the piping and replacement of two district regulators at the Arthur Avenue station. The cost of this modification is approximately $200,000 and would not incur a parasitic electric load.

Proposed CHP System Integration to the Central Boiler Plant

The proposed location for the twin OPRA16 turbines is within the utility yard on the north side of the boiler plant. From this spot, the high temperature exhaust ducts can enter the building and connect to a new Heat Recovery Steam Generator (HRSG) unit that will be located in place of existing boiler B-3. The HRSG will have the capability to produce 180-200 psi steam that will be routed to a new steam turbine (STG) located on a platform above the HRSG. The new high-efficiency dual-pressure STG, replacing the existing STG, will have the capability to provide 30 psi steam to the campus heating system; it will also have the capability to handle steam flows in excess of the heating demand by condensing that steam for additional power production. A new condenser and cooling tower combination will be installed to provide this capability.

The proposed HRSG is a firetube type with an integral dual-fuel fired burner for supplemental firing. This unit is also equipped with bypass ducts and dampers and economizer section for further heat recovery as required for boiler feedwater. The supplemental firing capability of the HRSG is 50,000 pph; which in combination with an upgraded boiler B-2 at 30,000 pph totals a capacity of 80,000 pph backup heating capacity.

To provide enough dual-fuel firing capability during a gas curtailment, it is recommended that boiler B-1 be renovated with two dual fuel, low NOx burners to provide this capability as well as lowering emissions. B-1 should also be retrofit with a 10’ stack extension to replace the existing roof-mounted hood to significantly improve the atmospheric dispersion characteristics for this unit. Boiler B-2 can be brought up to its former rated capacity of 30,000 pph by replacement of the FD fan motor and variable speed drive.

The OPRA16 turbines have dual fuel capability and can provide power generation capability during a natural gas curtailment, if desired. New controls shall be installed to sequence the new CHP equipment with the existing boiler plant including new graphic workstations.

It is proposed that the turbines be supported on an elevated platform (approximately 5’ above grade) with steel framework built upon helical piers that are strategically placed to avoid buried utilities. The elevated platform would allow access to any buried utilities located below the turbines as opposed to a concrete slab on grade.

Air Quality Permit

Currently, the existing boiler plant does not have an air quality permit since the boilers were in existence before regulations were put in place. The proposed CHP project would be a significant modification to the plant and would trigger a review of the proposed emission rates for criteria pollutants. Nitrogen oxides (NOx) will be the primary pollutant of concern. The air quality permit review would require air quality modeling to determine compliance with the National Ambient Air Quality Standards (NAAQS). A discussion with the consultant who developed a previous study for the proposed UM biomass plant (Bison Engineering) said that the most likely concern would be a violation of the 1-hr NOx standard due to poor atmospheric diffusion from Boilers B-1 and B-3 whose combustion vents terminate in roof-mounted hoods, and the proximity of Aber Hall which can a cause a high NOx concentration. Boiler B-3 will be replaced with the new HRSG that will have a 10’ stack; boiler B-1 can be retrofit with a 10’ stack and high-efficiency, low-NOx burners to replace the original 1962 burners. Boiler B-2 is connected to the 150’ stack and will not cause a 1-hr NOx exceedance due to atmospheric diffusion. The turbines themselves will be equipped with low-NOx burners that will produce NOx concentrations below 25 ppmv.

CHP Electrical Integration

Existing Electrical Service and Distribution

The primary electrical feed for the campus is from a dedicated utility company 12.47kV feeder that originates in Northwestern Energy's downtown Missoula substation. This feed terminates on the University of Montana campus in a Northwestern Energy 12.47kV primary meter package located north of the heating plant building. The electrical distribution system downstream of Northwestern Energy's primary meter is owned and operated by the University of Montana. The primary meter package feeds a pad mounted VFI switchgear unit. The VFI switchgear distributes power throughout the campus via four underground power loops.

The main Northwestern Energy feeder and primary meter package along with the VFI switchgear were recently installed (summer/fall of 2016). This equipment replaced the obsolete main switchgear and re-routed the main Northwestern Energy feeder to accommodate the new Champion Center Building that is currently under construction.

A secondary 12.47kV Northwestern Energy feeder from Arthur Avenue ties into the campus distribution at the Knowles Building. This feed is utilized as a backup and is energized only if the primary feed has failed. Load shedding is required in order to use the Arthur Avenue feed since it does not have enough capacity to feed the entire campus load.

The existing emergency/standby/backup power generators on campus consists of (29) engine generators located at various buildings throughout the campus. These generators supply power to emergency lighting and critical loads in the event of a utility grid power outage. Both natural gas and diesel fuel is utilized as the fuel source for these generators. The total nameplate capacity of these generators is 2,315kW. The campus is also equipped with a 450kW steam driven turbine generator. This generator operates in in grid parallel base load mode to offset the amount of power imported from the grid. Since this generator is an induction type generator, it will automatically go off line in the event of a grid failure and therefore it is not utilized as a backup power source.

Northwestern Energy Interconnection Requirements

Distributed generation plants that operate in parallel with the grid are required to develop an interconnection agreement with Northwestern Energy. The interconnection process involves a detailed study conducted by Northwestern Energy. This study evaluates the impact the CHP generation and interconnection will have on the grid and determine if upgrades to North Western Energy's system will be required such as upgrades to their substation line re-closers, line regulators, or capacitor banks. An allowance in the project budget has been included for the Northwestern Energy interconnection study fees and fees associated with their system upgrades. The exact cost of the upgrades, if required, will not be available until after Northwestern Energy's impact study is complete. This study is a lengthy process that can take 6 months or longer. It is recommended that the interconnection application be submitted prior to starting the major engineering design for the project.

The interconnection of the CHP plant will be required to follow Northwestern Energy's Interconnection Guidelines for Small Generation. Small generation is considered any plant that has an aggregate capacity of 10MW or less. These guidelines require compliance with the IEEE 1547 standards as well as the following:

1) A utility grade protective relay will be required to be installed at the point of common coupling (CHP plant interconnection point). The main function of this relay is to prevent the CHP from back feeding a dead utility grid in the event of a grid failure (anti-islanding function). The relay will trip the generator plant main breaker upon detection of the following:

    a. 81O/81U – Over frequency and under frequency.
    b. 27 – Under voltage.
    c. 59 – Over voltage.
    d. 32R – Reverse power.

    The settings for the protective relay will be required to be in compliance with the IEEE 1547 standards.

2) A visible break isolation disconnection switch will be required at the point of interconnection of CHP plant. The existing switches in the campus primary power VFI switchgear will satisfy this requirement. The draw-out circuit breakers located in the CHP generator switchgear will also satisfy this requirement.

3) A direct transfer trip "DTT" system from Northwester Energy's substation or line re-closer will most likely be required since the campus is fed from a dedicated feeder. IEEE 1547 recommends DTT if the CHP generating capacity exceeds 30% of the minimum load on the NWE feeder serving the site. The purpose of the DTT system is to send a signal to the CHP generator breakers and disconnect the generator plant from the grid in the event that the NWE substation re-closer detects a fault on the feeder serving the campus.

4) Prior to operating the CHP plant in parallel with the grid, Northwestern Energy will require a pre-parallel inspection of the interconnection equipment and protective relay. Additionally, Northwestern Energy will require detailed testing of the protective relay including an in service functional test.

Modes of Operation

The proposed modes operation for the CHP will include the following:

1) <u>Base Load</u>: In base load operation, the CHP plant will operate in parallel with the grid and supply power to the campus. The generators will modulate their power production to match the campus load (load following). A minimum amount of power will be imported from the grid to prevent activation (nuisance tripping) of the reverse power relay if a large load is turned off. Importing a small amount of power (approx. 75kW) at all times

will provide a buffer to give the generators time to decrease their power output if a large load is shut down.

2) Island Mode: Island mode operation consists of utilizing the CHP generators to supply power to the campus in the event of a utility grid failure. In order to use the CHP plant in island mode, the campus electrical distribution system will have to be isolated from the grid. This can be achieved by opening the main switch in the campus primary power VFI switchgear. A comprehensive load management system will also need to be developed in order to operate in island mode. The load management system will perform the following functions:

    a. The load management system will be utilized for load shedding. Deactivating a portion of the campus loads during peak demand periods will be required because the campus peak load exceeds the power production capacity of the proposed CHP generators.

    b. The load management system will also be utilized for step loading the generator plant during a black start up when the utility grid power has failed. A typical turbine can only handle an initial block load of about 45% of its nameplate rating. After the initial block load, the generators can typically only handle step loads of 20% increments until full load is reached. The campus load will need to be controlled to accommodate these load increments.

3) Export Mode: In export mode, the load following function and reverse power relay will be deactivated and the generator plant will operate at a fixed power output. Excess power not utilized on the campus will be exported to the grid for purchase. The control system can be configured to allow automatic export activation to allow exporting to occur only during specific times of the day/month/year to coincide with the highest purchase rates (on peak rates) if applicable in the power purchase rate structure.

    The options for power purchase include the following:

    a. Sell power to Northwestern Energy. To sell power to NWE, the CHP plant will have to be certified by the Federal Energy Regulatory Commission as a Qualifying Facility "FERC QF".

    b. Sell wholesale power on the open access transmission system.

    To sell power back to Northwestern Energy, a power purchase agreement will have to be developed. The exact purchase rate is unknown at this time because the standard QF-1 rate Tariff is not applicable to this project since the proposed nameplate capacity of the CHP generators exceeds 3,000kW. According to Frank Bennett with NWE, the power purchase rates for facilities that have a rating that exceeds 3,000kW are based on a study conducted by NWE. This study consists of an economic evaluation based on the need for power in the area where the CHP plant located.

Load Management System

As stated above, a compressive load management system is required in order to operate the CHP plant in island mode to supply power to the campus during a grid failure. A detailed evaluation of the campus distribution system and loads will need to be conducted in order to determine the best method for controlling (load shed and step loading) the campus electrical loads. A priority list will need to be developed to determine the load shedding and step loading order. Lower priory loads will be shed first while maintaining power to the higher priority/critical loads.

The load management system can be an automated system that is controlled by the generator PLC system or by manual control from the plant operator. A manual control system will be far less expensive than an automated system but will take about 45 minutes to implement in the event of a grid failure.

The following is a preliminary list of the loads that can be controlled utilizing existing electrical gear and systems:

1) The main campus VFI switchgear distributes power to the campus via four underground 12.47kV feeders. Each feeder in the campus primary distribution system is fed from a dedicated switch/vacuum fault interrupter device that can be controlled by the CHP generator plant load management system. Motor operators will need to be added to each switch/VFI to interface with the generator load management system. The following is approximate peak load for each feeder:

    a. Stadium Feed: 1,871 kW
    b. North Loop: 1,946 kW
    c. Center Loop: 2,550 kW
    d. South Loop: 1,133 kW

2) The campus energy management system can be utilized to load shed/step load the heating, cooling, and lighting systems throughout the campus. The CHP generator load management system can send load shed/load add signals to the campus energy management system to command the heating/cooling/lighting loads to be turned on/off when needed.

3) The existing campus emergency/standby generators can be utilized to supplement the power produced by the CHP generator system and step load the CHP generator plant. The CHP load management system can send an inhibit/permissive signal to the existing emergency generator transfer switches. These signals will command each emergency generator to remain on line and supply power to their respective load until the CHP load control system is ready for that particular load to be added to the CHP generator plant bus.

CHP Electrical Interconnection and Distribution System

The proposed CHP plant consists of two 1,600 kW gas turbine generators and one 1,200kW steam turbine generator. The preferred operating voltage for these generators is 12.47 kV. This voltage will directly match the voltage of the campus primary distribution system. Another common voltage for the generators is 480 volts. This voltage is much less desirable than 12.47Kv because the feeder sizes at 480 volts will be very large and the 480-volt output would have to be increased to match the campus 12.47kV system utilizing step up transformers.

The proposed generator plant will be equipped with 12.47kV medium voltage paralleling switchgear to allow the output of each generator to be synchronized with each other and the Northwestern Energy grid. The switchgear will be equipped with a PLC control system for control of the breakers and to perform generator control (paralleling functions, load management functions, generator load share, etc.).

The proposed interconnection point for the output of the generator paralleling switchgear is at the existing spare switch in the campus primary power main VFI switchgear. This tie in point is downstream (campus side) of the existing Northwestern Energy meter. This tie in point allows for behind the meter generation to allow the power produced by the CHP plant to reduce the power purchased from the grid at retail rates (primary power meter rate structure).

The proposed CHP electrical distribution system will need to include an onsite backup power generator to supply power to the CHP equipment to accommodate a black start of the plant for island mode operation in the event of a utility grid power outage. These loads include the ventilation fans, the turbine starting motor, and other misc. motors (roughly 350KW of load).

State Historical Preservation Office (SHPO) Concerns

The University of Montana Central Heating Plant was constructed in 1922, based on the designs provided by architects Ole Bakke & C.H. Forbis - with George H. Carsley acting as consulting architect – and Charles L. Pillsbury Co., consulting engineer from Minneapolis/St. Paul. The former pair designed the main portion of the building and the latter designed the 150-foot-tall smokestack and the tall coal storage structure at the east side of the building. The main portion of the building is of the Renaissance Revival style, whereas the coal storage structure is more utilitarian with its honest expression of concrete framing and brick infill.[1]

Compliance with Montana State Antiquities Act

The Montana State Antiquities Act, MCA 22-3-421 to MCA 22-3-442, establishes and defines the responsibilities of state agencies – and the Montana university system – for worked planned on heritage properties. Administrative Rule 10.121.903 requires the university to initiate review of the project – in its early planning stages - by the State Historic Preservation Office (SHPO). To this end, CTA has initiated discussions with SHPO, with the advisement that a representative from the University of Montana will be required to carry this conversation forward with SHPO, in full adherence of the rules.

Heritage Property: the University of Montana Boiler Plant, constructed in 1922, is considered a contributing resource to the University of Montana Historic District (Smithsonian # 24MO0471), thus is a heritage property. SHPO consultation is required.

Preliminary Consultation

CTA's Historic Preservation Services director Lesley M. Gilmore initiated preliminary discussions with Pete Brown (Historic Preservation Specialist) of the State Historic Preservation Office, to enable CTA's design team to offer solutions that will be viable and acceptable to the SHPO. These preliminary discussions will need to be continued by the University of Montana.

The following design parameters for the turbine location were agreed upon with SHPO:

1. The primary west and south facades of the building should be left intact and not modified.
2. Preferable: Do not construct an addition onto the building.
3. Locate the turbines on the grade-level lot north of the building.
4. Turbine color shall be unobtrusive.
5. Consider enclosing the turbines to soften the appearance and have it blend more with the building. Enclosure could be close-web wired fencing with vines or a brick wall.

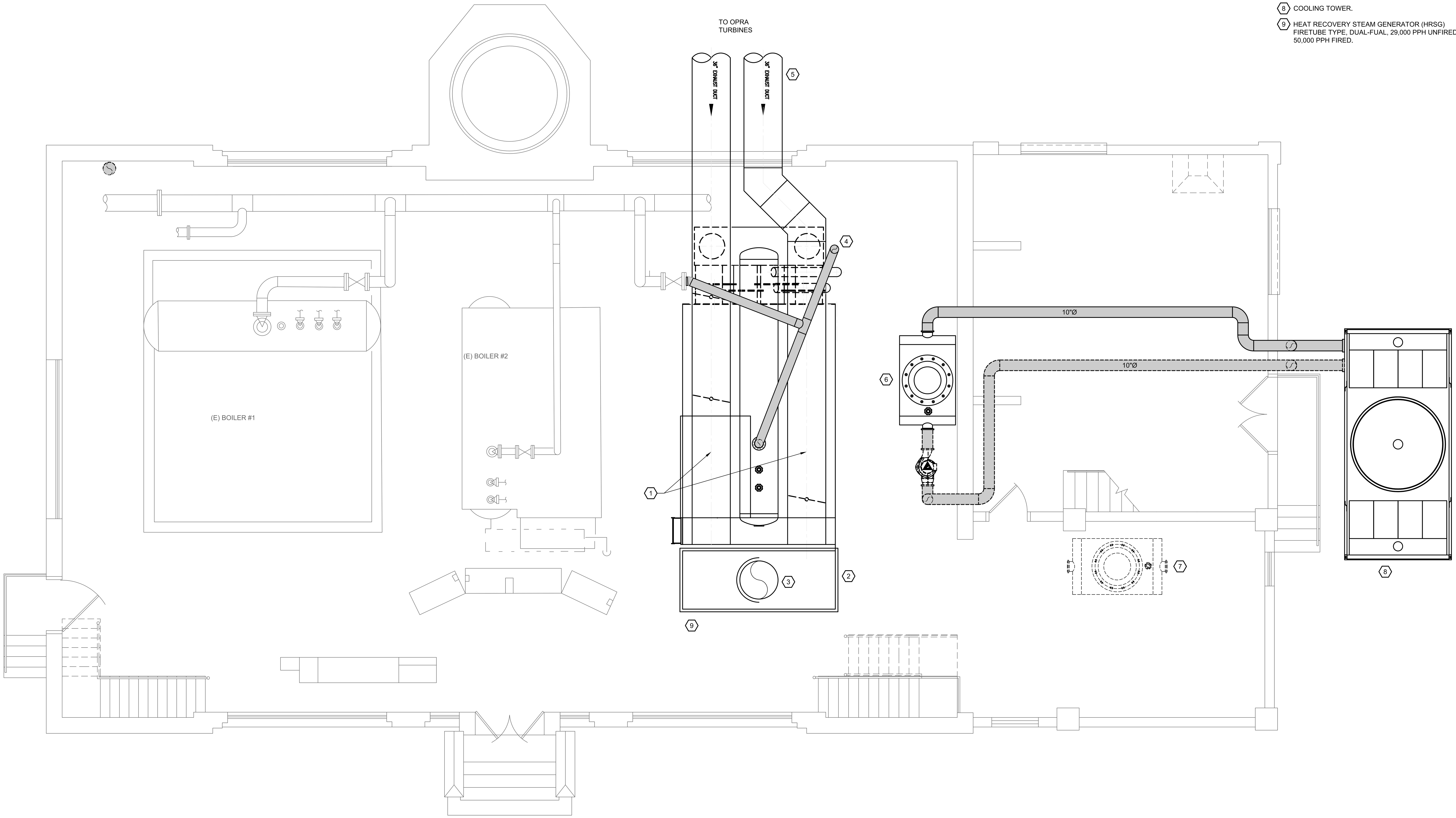
[1] SHPO, "University of Montana Central Heating Plant – Site No. 1199," provided by SHPO.

If it is desired to expand or relocate the workshop, it would be possible to add an underground level adjacent to the existing basement. The estimated cost of this addition is $700,000.

Appendix A – Drawings

SHEET NOTES

1. HRSG BYPASS DUCTS.
2. ECONOMIZER.
3. STACK.
4. HIGH PRESSURE STEAM TO STEAM TURBINE (STG) ABOVE.
5. GAS TURBINE 36" DIA. EXHAUST DUCTS.
6. SURFACE CONDENSER.
7. SURFACE CONDENSER (ALTERNATE LOCATION).
8. COOLING TOWER.
9. HEAT RECOVERY STEAM GENERATOR (HRSG) FIRETUBE TYPE, DUAL-FUAL, 29,000 PPH UNFIRED, 50,000 PPH FIRED.



1 M101 FIRST FLOOR MECHANICAL REMODEL PLAN

1/4"=1'-0"

0 2' 4' 8'

SCALE: 1/4" = 1'-0"

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MISSOULA MONTANA
CENTRAL HEATING PLANT UPGRADE
UNIVERSITY OF MONTANA

SCHEMATIC DESIGN

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REVISIONS
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MECHANICAL REMODEL PLAN

M101

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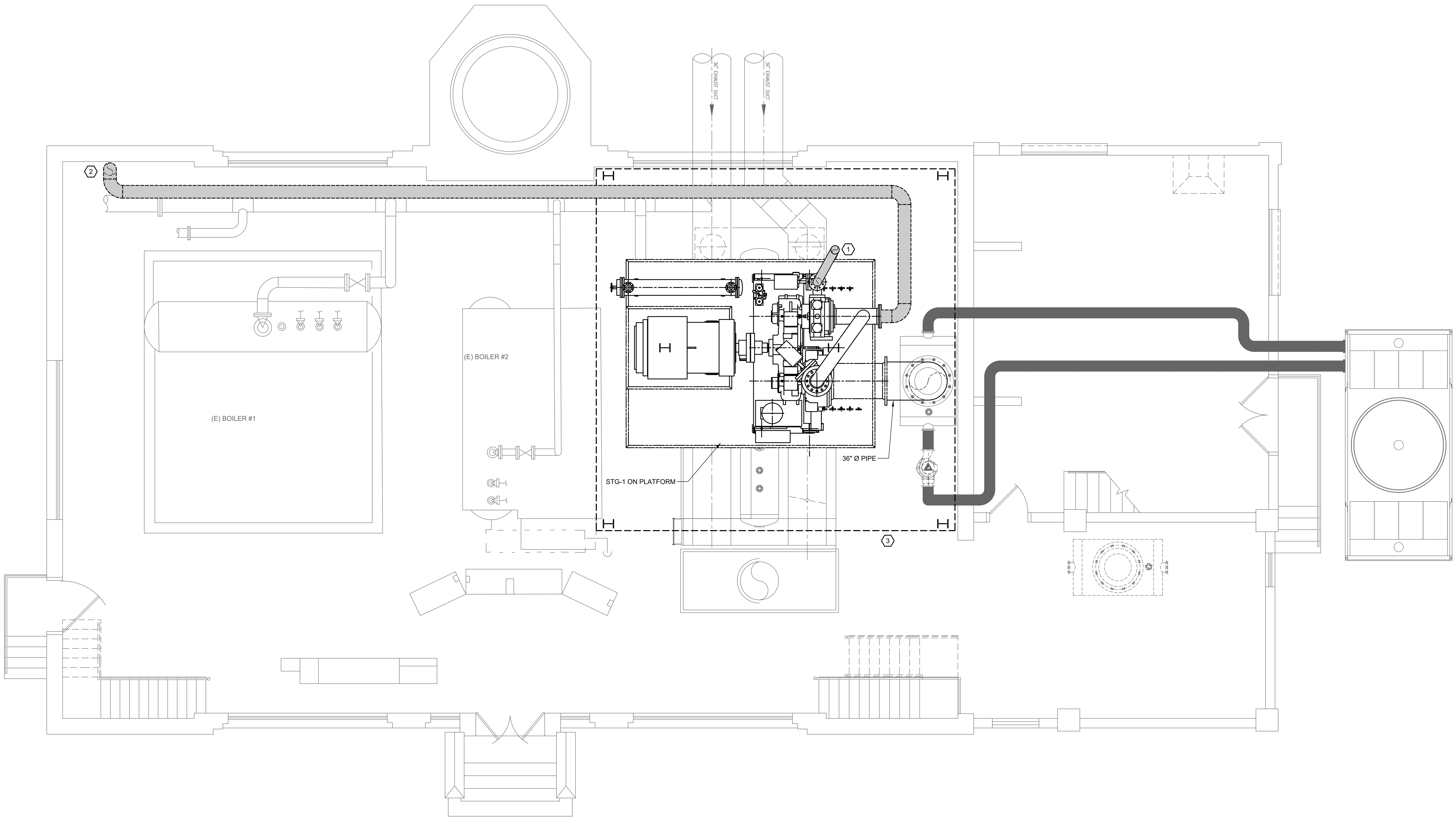
SHEET NOTES
1. HIGH PRESSURE STEAM FROM HRSG TO STG.
2. 30 PSI EXTRACTION STEAM LINE FROM NEW STG TO FORMER STG OUTLET.
3. PLATFORM AT 22' AFF.



1 M111 MEZZANINE MECHANICAL REMODEL PLAN
1/4"=1'-0"

SCALE: 1/4" = 1'-0"

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UNIVERSITY OF MONTANA

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MEZZANINE MECHANICAL REMODEL PLAN

M111

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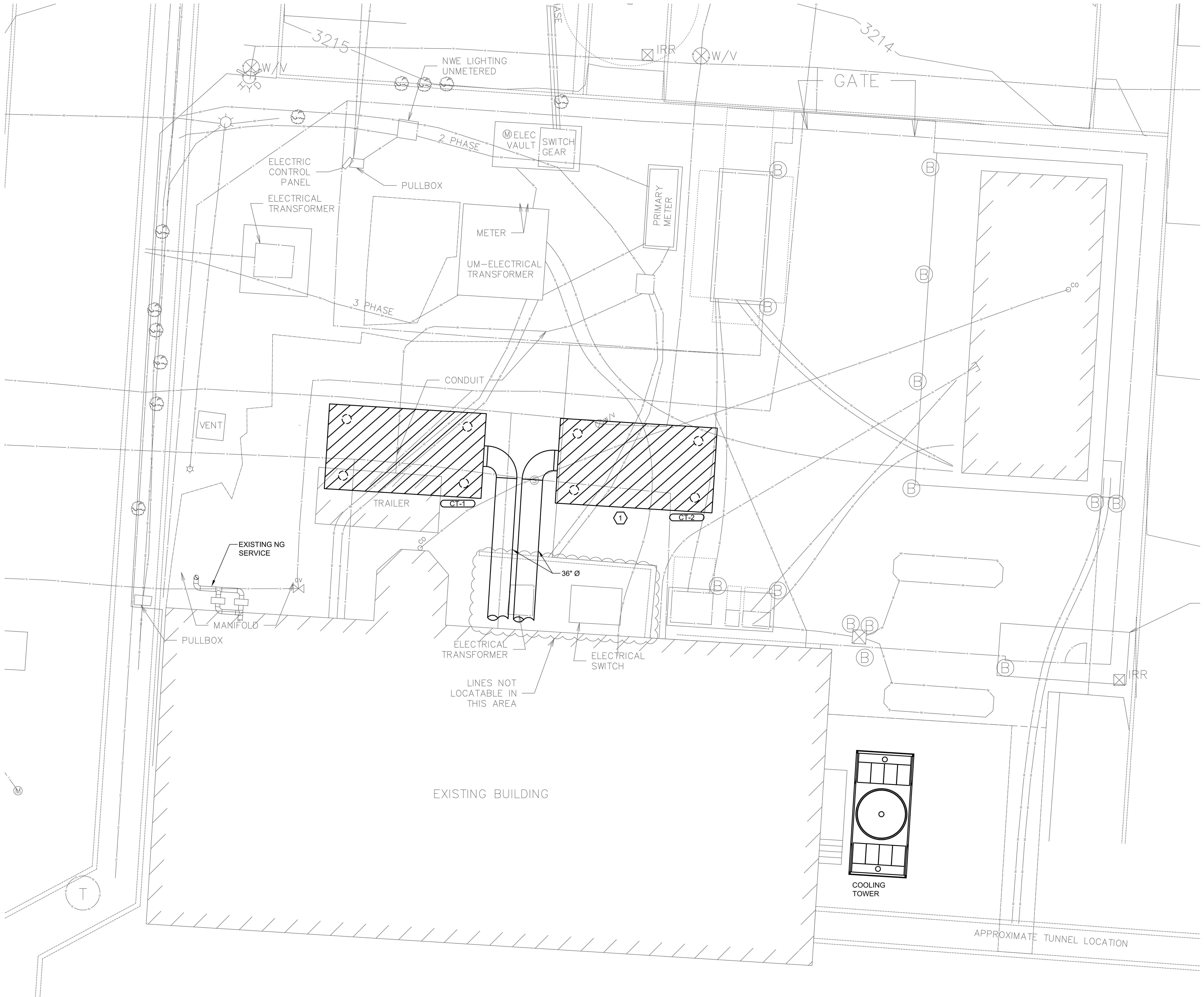
SHEET NOTES

1. NEW GAS TURBINES MOUNTED ON A PLATFORM 5' ABOVE GRADE SUPPORTED BY HELICAL PIERS AND STEEL FRAMEWORK.



1 M400 MECHANICAL SITE PLAN 1/8"=1'-0"

0 4' 8' 16'
SCALE: 1/8" = 1'-0"

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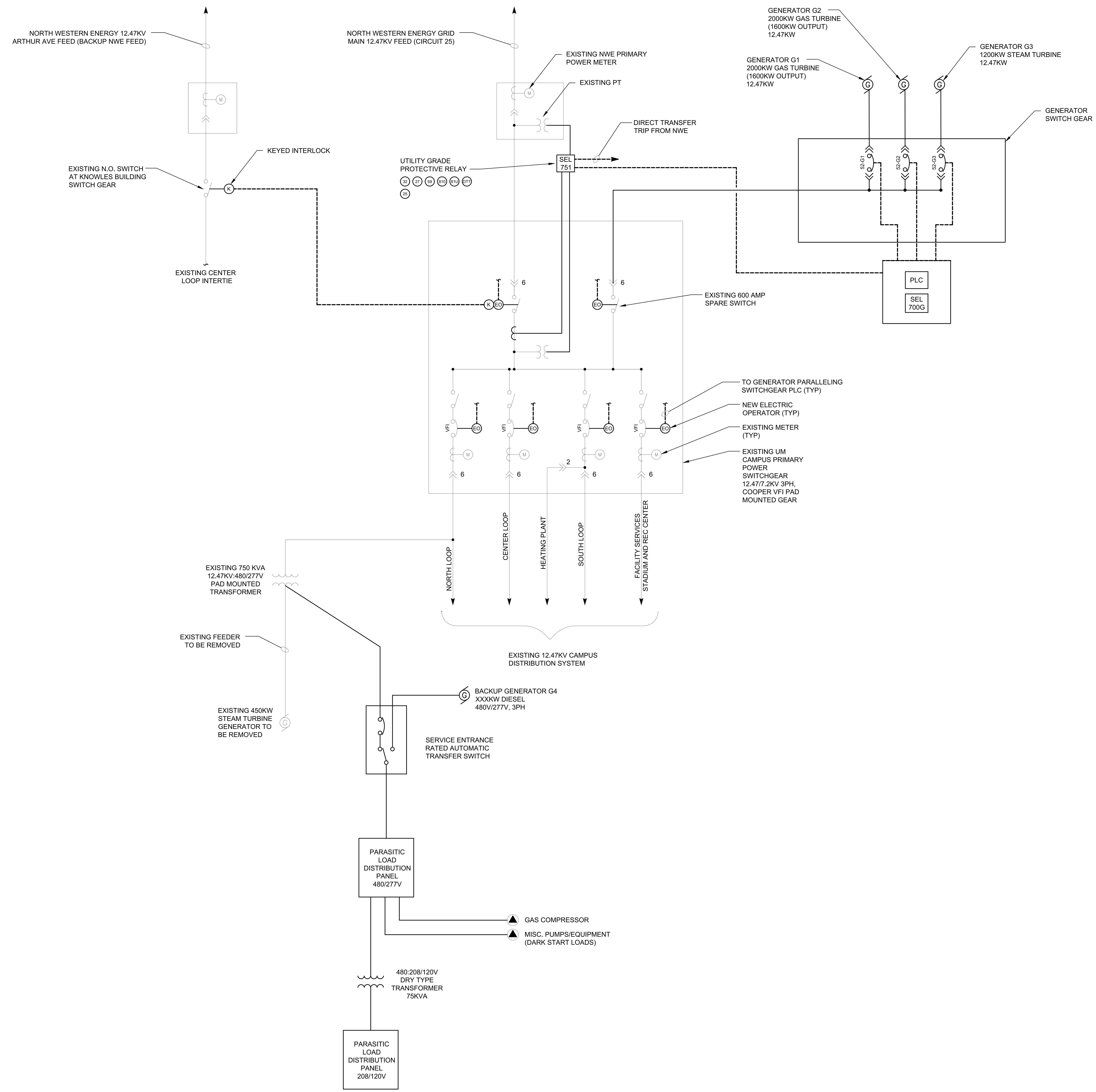
MECHANICAL SITE PLAN

M400



MODES OF OPERATION

Import/Load Follow:
Utility is available, generator G1, G2, and G3 operate in parallel with utility to provide base load power to the campus. Base load power shall be manually set via the HMI or remotely set via campus network. Power will be imported from the utility as required to meet the campus power demand. If the combined power output of generators G1, G2, and G3 exceeds the campus demand, the generator plant shall automatic adjust power output to follow the campus demand load. The generator control system will be set for a minimum amount of power to be imported from the grid to prevent a reverse power condition. If a large load turns off, the generator plant will need adequate time to modulate its output downward to prevent a reverse power condition (exporting power to the grid).

Export Mode:
Exporting power to the utility grid is not included in the modes of operation. The protective relay located at the campus primary service switch switch will detect reverse power conditions. Activation of the reverse power relay will trip the generator breakers 52-G1, 52-G2, and 52-G3.

Utility Fail:
Upon utility failure, the protective relay at the campus service gear will detect an under voltage and under frequency condition. This condition will trip the generator breakers 52-G1, 52-G2, 52-G3, and disconnect the system from the utility grid. Additionally, the utility company "NWE" will send a DTT (Direct Transfer Trip) signal from their substation relay upon detection of a fault on the feeder serving the campus. The DTT signal will also trip the generator main breaker 52GM.

Island Mode Option #1 (Manual):
Upon an extended utility failure, the plant operator will manually initiate a manual island mode operation by activating a Kirk Key switch at the 25kV service entrance gear. Activation of this switch will cause the utility service switch in the campus primary switchgear to open and be locked out during island mode operation. Plant operator will manually open breakers serving various facility loads (load shed). Plant operator will then utilize the Kirk Key to activate the island mode keyed switch located in the generator control cabinet. After all generators are on line and operating in parallel, the generator switch in campus switchgear will automatically close and energize the distribution system. The breakers serving the facility loads will then be manually turned on one at a time to maintain the step loading limitations of the CHP generator plant.

Island Mode Option #2 (Automatic):
Upon utility failure, generator breakers 52-G1, 52-G2, and 52-G3 will open as described above. Generator control system will open the service switch and the distribution switches in the campus primary switchgear. Generator G4 will start and supply power to the gas compressor and other components required for a black start. Generators G1, G2, and G3 will start and parallel to the CHP switchgear bus. After all three generators are operating in parallel, generator switch in campus switchgear will close. Distribution switches in the campus primary gear will close one at a time to resume power to the campus. Generator load management system will monitor campus load and shed load by opening the distribution switches in the campus primary gear should a bus overload occur.

RELAY SETTING REQUIREMENTS

25	SYNCHRO-CHECK RELAY
27	UNDER VOLTAGE RELAY
32	REVERSE POWER RELAY
59	OVER VOLTAGE RELAY
81U	UNDER FREQUENCY RELAY
81O	OVER FREQUENCY RELAY
TT	TRANSFER TRIP FUNCTION FROM UTILITY COMPANY TO TRIP THE GENERATOR MAIN BREAKER

LINE	KEY INDEX
(light line)	EXISTING TO REMAIN (E)
(solid line)	NEW WORK (N)
(dashed line)	CONTROL WIRING

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UNIVERSITY OF MONTANA
CONCEPT CHP SYSTEM

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ELECTRICAL
CONCEPT ONE LINE
DIAGRAM

E001

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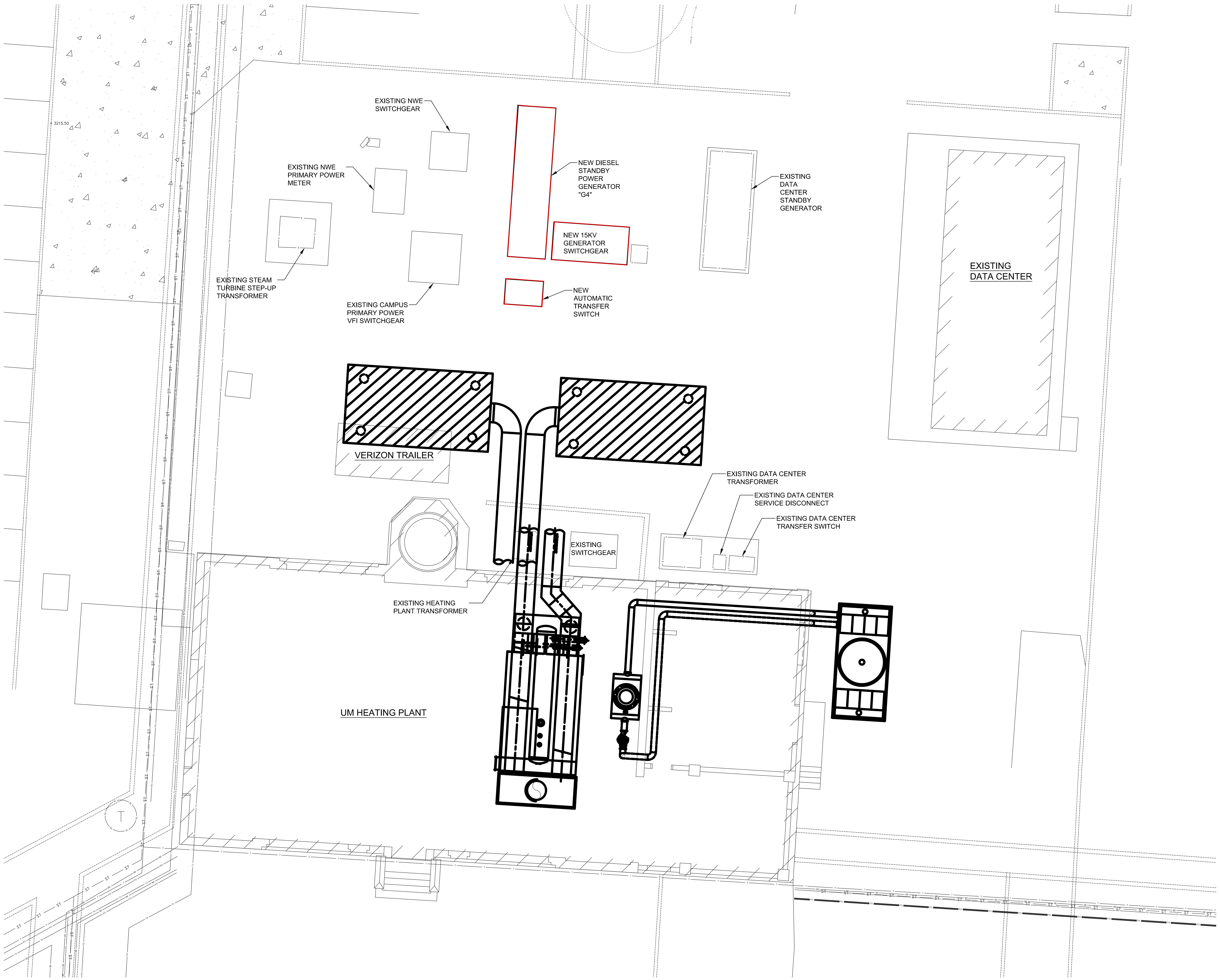

1
E002
ELECTRICAL CONCEPT PLAN
1/8"=1'-0"

NORTH REF.

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CONCEPT CHP SYSTEM

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ELECTRICAL
SITE PLAN

E002

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Appendix B – Cost Estimates

Total

Project:	**University of Montana CHP**	**OPRA Turbines**
Location	Missoula MT	
Date	10/18/2016	
Constants:		
Labor Multiplier	100%	
Material Multiplier	100%	

Opinion of Probable Total Cost

Description	QTY	Units	$/Unit Matl.	$/Unit Labor	Matl Mult.	Labor Mult.	TOTAL
Electric Cost Estimate	1	LS					$ 1,086,937
Mechanical Cost Estimate	1	LS					$ 10,291,350
Engineering Design and Project Management	6.25%	LS					$ 711,143
SUB TOTAL							$ 12,089,430

Mechanical

Project:	University of Montana CHP
Location	Missoula MT
Date	10/10/2016
Constants:	
Labor Multiplier	100%
Material Multiplier	100%

Opinion of Probable Cost - Mechanical - (2) 1600kW Gas Turbines; (1) Firetube HRSG; and (1) 1200kW Steam Turbine

Description	QTY	Units	$/Unit Matl.	$/Unit Labor	Matl Mult.	Labor Mult.	TOTAL
Mechanical							
Two OP16 Gas Turbines w/Arctic Package and Weather Hoods, dual fuel	1	LS	$ 3,825,000.00	$ 45,000.00	100%	100%	$ 3,870,000
Turbine helical pier support structure and framework	2	Ea.	$ 16,000.00	$ 16,000.00	100%	100%	$ 64,000
HRSG package, firetube type, integral bypass & economizer, dual fuel, 50k pph	1	LS	$ 1,050,000.00	$ 150,000.00	100%	100%	$ 1,200,000
1.2 MW Steam Turbine Generator Set, dual pressure	1	Ea.	$ 1,400,000.00	$ 65,000.00	100%	100%	$ 1,465,000
Mezzanine structural platform for steam turbine	1	LS	$ 200,000.00	$ 100,000.00	100%	100%	$ 300,000
Surface Condenser & Cooling Tower	1	Ea.	$ 400,000.00	$ 75,000.00	100%	100%	$ 475,000
New steam piping, feedwater piping, valves, appurtenances	1	LS	$ 350,000.00	$ 300,000.00	100%	100%	$ 650,000
On-site natural gas piping and fuel oil piping	1	LS	$ 50,000.00	$ 75,000.00	100%	100%	$ 125,000
Off-site high-pressure natural gas regulation modifications (new regulators)	1	LS	$ 150,000.00	$ 50,000.00	100%	100%	$ 200,000
Stack extension, 10', existing boiler B-1	1	Ea.	$ 15,000.00	$ 7,500.00	100%	100%	$ 22,500
Dual-fuel burner retrofit for B-1, Low-Nox	1	LS	$ 110,000.00	$ 65,000.00	100%	100%	$ 175,000
New VFD, Boiler B-2 FD Fan	1	LS	$ 20,000.00	$ 5,000.00	100%	100%	$ 25,000
Environmental permit	1	LS	$ -	$ 100,000.00	100%	100%	$ 100,000
Boiler demolition, B-3	1	LS	$ -	$ 45,000.00	100%	100%	$ 45,000
Steam turbine demolition, existing 450 kW	1	LS	$ -	$ 7,500.00	100%	100%	$ 7,500
Building Demolition (window removal & replacement)	1	LS	$ -	$ 25,000.00	100%	100%	$ 25,000
Controls Integration	1	LS	$ 75,000.00	$ 75,000.00	100%	100%	$ 150,000
Testing/commissioning	1	L.S.	$ -	$ 50,000.00	100%	100%	$ 50,000
Mechanical contingency and general conditions (mob/de-mob, general materials, etc)	15%	L.S.					$ *1,342,350*
Subtotal							
TOTAL							$ 10,291,350

Electrical

Project:	University of Montana CHP
Location	Missoula MT
Date	10/10/2016
Constants:	
Labor Multiplier	100%
Material Multiplier	100%

Opinion of Probable Cost - Electrical - (2) 1600kW Gas Turbines and (1) 1200kW Steam Turbine and Automatic Island Mode Operation

Description	QTY	Units	$/Unit Matl.	$/Unit Labor	Matl Mult.	Labor Mult.	TOTAL
Electrical							
Cut and Patching	500	L.F.		$ 22.75	100%	100%	$ 11,375
Trenching and Backfill	500	L.F.		$ 27.00	100%	100%	$ 13,500
Core walls and floors (core drill manhole MH#5)	1	L.S.		$ 1,500.00	100%	100%	$ 1,500
125 AMP Feeder 480 volt	50	L.F.	$ 10.05	$ 15.70	100%	100%	$ 1,288
225 AMP Feeder 480 volt	150	L.F.	$ 23.50	$ 23.50	100%	100%	$ 7,050
600 AMP Feeder 480 volt	250	L.F.	$ 87.50	$ 77.00	100%	100%	$ 41,125
15kV 150 amp feeder (concrete encased)	350	L.F.	$ 43.25	$ 58.00	100%	100%	$ 35,438
Medium voltage cable terminations	12	E.A.	$ 360.00	$ 114.00	100%	100%	$ 5,688
Utility grade protective relay SEL751	1	E.A.	$ 3,500.00	$ 2,500.00	100%	100%	$ 6,000
Retrofit existing switchgear with motor operators	6	L.S.	$ 3,200.00	$ 1,000.00	100%	100%	$ 25,200
Generator paralleling gear and controls	1	L.S.	$ 275,000.00	$ 45,000.00	100%	100%	$ 320,000
480 volt and 280/120 v distribution gear	1	L.S.	$ 25,000.00	$ 12,000.00	100%	100%	$ 37,000
500kW diesel generator and transfer switch	1	L.S.	$ 150,000.00	$ 45,000.00	100%	100%	$ 195,000
Northwestern Energy Direct Transfer Trip Equipment	1	L.S.	$ 15,000.00	$ 5,000.00	100%	100%	$ 20,000
Misc wiring and feeders	1	L.S.	$ 25,000.00	$ 25,000.00	100%	100%	$ 50,000
Load control system	1	L.S.	$ 75,000.00	$ 50,000.00	100%	100%	$ 125,000
Load control wiring to BAS/chillers	1	L.S.	$ 5,000.00	$ 5,000.00	100%	100%	$ 10,000
Testing/commissioning	1	L.S.		$ 40,000.00	100%	100%	$ 40,000
Electrical contigency and general conditions (mob/de-mob, general materials, etc)	15%	L.S.					$ *141,774*
				$ 391,327,748.00			
TOTAL							$ 1,086,937

Total

Project:	**University of Montana CHP**	**Solar Centaur 50 turbine**
Location	Missoula MT	
Date	10/18/2016	
Constants:		
Labor Multiplier	100%	
Material Multiplier	100%	

Opinion of Probable Total Cost

Description	QTY	Units	$/Unit Matl.	$/Unit Labor	Matl Mult.	Labor Mult.	TOTAL
Electric Cost Estimate	1	LS					$ 1,086,937
Mechanical Cost Estimate	1	LS					$ 11,097,500
Engineering Design and Project Management	6.25%	LS					$ 761,527
SUB TOTAL							$ 12,945,965

Mechanical

Project:	University of Montana CHP
Location	Missoula MT
Date	10/10/2016
Constants:	
Labor Multiplier	100%
Material Multiplier	100%

Opinion of Probable Cost - (1) Solar Centaur 50 Gas Turbine; (1) Watertube HRSG; and (1) 1200 kW Steam Turbine

Description	QTY	Units	$/Unit Matl.	$/Unit Labor	Matl Mult.	Labor Mult.	TOTAL
Mechanical							
Solar Centaur 50 Gas Turbine, dual fuel	1	LS	$ 3,900,000.00	$ 45,000.00	100%	100%	$ 3,945,000
Turbine helical pier support structure and framework	1	Ea.	$ 20,000.00	$ 20,000.00	100%	100%	$ 40,000
HRSG package, watertube type, bypass damper, dual fuel duct burner w fresh air mode	1	LS	$ 1,750,000.00	$ 150,000.00	100%	100%	$ 1,900,000
1.2 MW Steam Turbine Generator Set, dual pressure	1	Ea.	$ 1,400,000.00	$ 65,000.00	100%	100%	$ 1,465,000
Mezzanine structural platform for steam turbine	1	LS	$ 175,000.00	$ 75,000.00	100%	100%	$ 250,000
Surface Condenser & Cooling Tower	1	Ea.	$ 400,000.00	$ 75,000.00	100%	100%	$ 475,000
New steam piping, feedwater piping, valves, appurtenances	1	LS	$ 350,000.00	$ 300,000.00	100%	100%	$ 650,000
On-site natural gas piping and fuel oil piping	1	LS	$ 50,000.00	$ 75,000.00	100%	100%	$ 125,000
Off-site high-pressure natural gas regulation modifications (new regulators)	1	LS	$ 150,000.00	$ 50,000.00	100%	100%	$ 200,000
Stack extension, 10', existing boiler B-1	1	Ea.	$ 15,000.00	$ 7,500.00	100%	100%	$ 22,500
Dual-fuel burner retrofit for B-1, Low-Nox	1	LS	$ 110,000.00	$ 65,000.00	100%	100%	$ 175,000
New VFD, Boiler B-2 FD Fan	1	LS	$ 20,000.00	$ 5,000.00	100%	100%	$ 25,000
Environmental permit	1	LS	$ -	$ 100,000.00	100%	100%	$ 100,000
Boiler demolition, B-3	1	LS	$ -	$ 45,000.00	100%	100%	$ 45,000
Steam turbine demolition, existing 450 kW	1	LS	$ -	$ 7,500.00	100%	100%	$ 7,500
Building Demolition (window removal & replacement)	1	LS	$ -	$ 25,000.00	100%	100%	$ 25,000
Controls Integration	1	LS	$ 75,000.00	$ 75,000.00	100%	100%	$ 150,000
Testing/commissioning	1	L.S.	$ -	$ 50,000.00	100%	100%	$ 50,000
Mechanical contingency and general conditions (mob/de-mob, general materials, etc)	15%	L.S.					*$ 1,447,500*
Subtotal							
TOTAL							**$ 11,097,500**

Electrical

Project: University of Montana CHP
Location Missoula MT
Date 10/10/2016
Constants:
Labor Multiplier 100%
Material Multiplier 100%

Opinion of Probable Cost - (1) Solar Centaur 50 Gas Turbine; (1) Watertube HRSG; and (1) 1200 kW Steam Turbine & Automatic Island Mode

Description	QTY	Units	$/Unit Matl.	$/Unit Labor	Matl Mult.	Labor Mult.	TOTAL
Electrical							
Cut and Patching	500	L.F.		$ 22.75	100%	100%	$ 11,375
Trenching and Backfill	500	L.F.		$ 27.00	100%	100%	$ 13,500
Core walls and floors (core drill manhole MH#5)	1	L.S.		$ 1,500.00	100%	100%	$ 1,500
125 AMP Feeder 480 volt	50	L.F.	$ 10.05	$ 15.70	100%	100%	$ 1,288
225 AMP Feeder 480 volt	150	L.F.	$ 23.50	$ 23.50	100%	100%	$ 7,050
600 AMP Feeder 480 volt	250	L.F.	$ 87.50	$ 77.00	100%	100%	$ 41,125
15kV 150 amp feeder (concrete encased)	350	L.F.	$ 43.25	$ 58.00	100%	100%	$ 35,438
Medium voltage cable terminations	12	E.A.	$ 360.00	$ 114.00	100%	100%	$ 5,688
Utility grade protective relay SEL751	1	E.A.	$ 3,500.00	$ 2,500.00	100%	100%	$ 6,000
Retrofit existing switchgear with motor operators	6	L.S.	$ 3,200.00	$ 1,000.00	100%	100%	$ 25,200
Generator paralleling gear and controls	1	L.S.	$ 275,000.00	$ 45,000.00	100%	100%	$ 320,000
480 volt and 280/120 v distribution gear	1	L.S.	$ 25,000.00	$ 12,000.00	100%	100%	$ 37,000
500kW diesel generator and transfer switch	1	L.S.	$ 150,000.00	$ 45,000.00	100%	100%	$ 195,000
Northwestern Energy Direct Transfer Trip Equipment	1	L.S.	$ 15,000.00	$ 5,000.00	100%	100%	$ 20,000
Misc wiring and feeders	1	L.S.	$ 25,000.00	$ 25,000.00	100%	100%	$ 50,000
Load control system	1	L.S.	$ 75,000.00	$ 50,000.00	100%	100%	$ 125,000
Load control wiring to BAS/chillers	1	L.S.	$ 5,000.00	$ 5,000.00	100%	100%	$ 10,000
Testing/commissioning	1	L.S.		$ 40,000.00	100%	100%	$ 40,000
Electrical contigency and general conditions (mob/de-mob, general materials, etc)	15%	L.S.					$ *141,774*
				$ 7,882,458,924.00			
TOTAL							**$ 1,086,937**

Total

Project:	**University of Montana CHP**	**Solar Mercury 50**
Location	Missoula MT	
Date	10/18/2016	
Constants:		
Labor Multiplier	100%	
Material Multiplier	100%	

Opinion of Probable Total Cost

Description	QTY	Units	$/Unit Matl.	$/Unit Labor	Matl Mult.	Labor Mult.	TOTAL
Electric Cost Estimate	1	LS					$ 1,086,937
Mechanical Cost Estimate	1	LS					$ 9,979,125
Engineering Design and Project Management	6.25%	LS					$ 691,629
SUB TOTAL							$ 11,757,691

Mechanical

Project:	University of Montana CHP
Location	Missoula MT
Date	10/10/2016
Constants:	
Labor Multiplier	100%
Material Multiplier	100%

Opinion of Probable Cost - Mechanical - (1) 4600 kW Gas Turbine & (1) HRSG

Description	QTY	Units	$/Unit Matl.	$/Unit Labor	Matl Mult.	Labor Mult.	TOTAL
Mechanical							
Solar Mercury 50 Gas Turbine, NG fuel	1	LS	$ 5,200,000.00	$ 45,000.00	100%	100%	$ 5,245,000
Turbine helical pier support structure and framework	1	Ea.	$ 20,000.00	$ 20,000.00	100%	100%	$ 40,000
HRSG package, watertube type, bypass damper, dual fuel duct burner w/fresh-air mode	1	LS	$ 1,750,000.00	$ 150,000.00	100%	100%	$ 1,900,000
							$ -
							$ -
							$ -
New steam piping, feedwater piping, valves, appurtenances	1	LS	$ 300,000.00	$ 275,000.00	100%	100%	$ 575,000
On-site natural gas piping and fuel oil piping	1	LS	$ 50,000.00	$ 75,000.00	100%	100%	$ 125,000
Off-site high-pressure natural gas regulation modifications (new regulators)	1	LS	$ 150,000.00	$ 50,000.00	100%	100%	$ 200,000
Stack extension, 10', existing boiler B-1	1	Ea.	$ 15,000.00	$ 7,500.00	100%	100%	$ 22,500
Dual-fuel burner retrofit for B-1, Low-Nox	1	LS	$ 110,000.00	$ 65,000.00	100%	100%	$ 175,000
New VFD, Boiler B-2 FD Fan	1	LS	$ 20,000.00	$ 5,000.00	100%	100%	$ 25,000
Environmental permit	1	LS	$ -	$ 100,000.00	100%	100%	$ 100,000
Boiler demolition, B-3	1	LS	$ -	$ 45,000.00	100%	100%	$ 45,000
			$ -				$ -
Building Demolition (window removal & replacement)	1	LS	$ -	$ 25,000.00	100%	100%	$ 25,000
Controls Integration	1	LS	$ 75,000.00	$ 75,000.00	100%	100%	$ 150,000
Testing/commissioning	1	L.S.	$ -	$ 50,000.00	100%	100%	$ 50,000
Mechanical contingency and general conditions (mob/de-mob, general materials, etc)	15%	L.S.					$ *1,301,625*
Subtotal							
TOTAL							$ 9,979,125

Electrical

Project:	University of Montana CHP
Location	Missoula MT
Date	10/10/2016
Constants:	
Labor Multiplier	100%
Material Multiplier	100%

Opinion of Probable Cost - Electrical - (1) Mercury 50 Gas Turbine and Automatic Island Mode Operation

Description	QTY	Units	$/Unit Matl.	$/Unit Labor	Matl Mult.	Labor Mult.	TOTAL
Electrical							
Cut and Patching	500	L.F.		$ 22.75	100%	100%	$ 11,375
Trenching and Backfill	500	L.F.		$ 27.00	100%	100%	$ 13,500
Core walls and floors (core drill manhole MH#5)	1	L.S.		$ 1,500.00	100%	100%	$ 1,500
125 AMP Feeder 480 volt	50	L.F.	$ 10.05	$ 15.70	100%	100%	$ 1,288
225 AMP Feeder 480 volt	150	L.F.	$ 23.50	$ 23.50	100%	100%	$ 7,050
600 AMP Feeder 480 volt	250	L.F.	$ 87.50	$ 77.00	100%	100%	$ 41,125
15kV 150 amp feeder (concrete encased)	350	L.F.	$ 43.25	$ 58.00	100%	100%	$ 35,438
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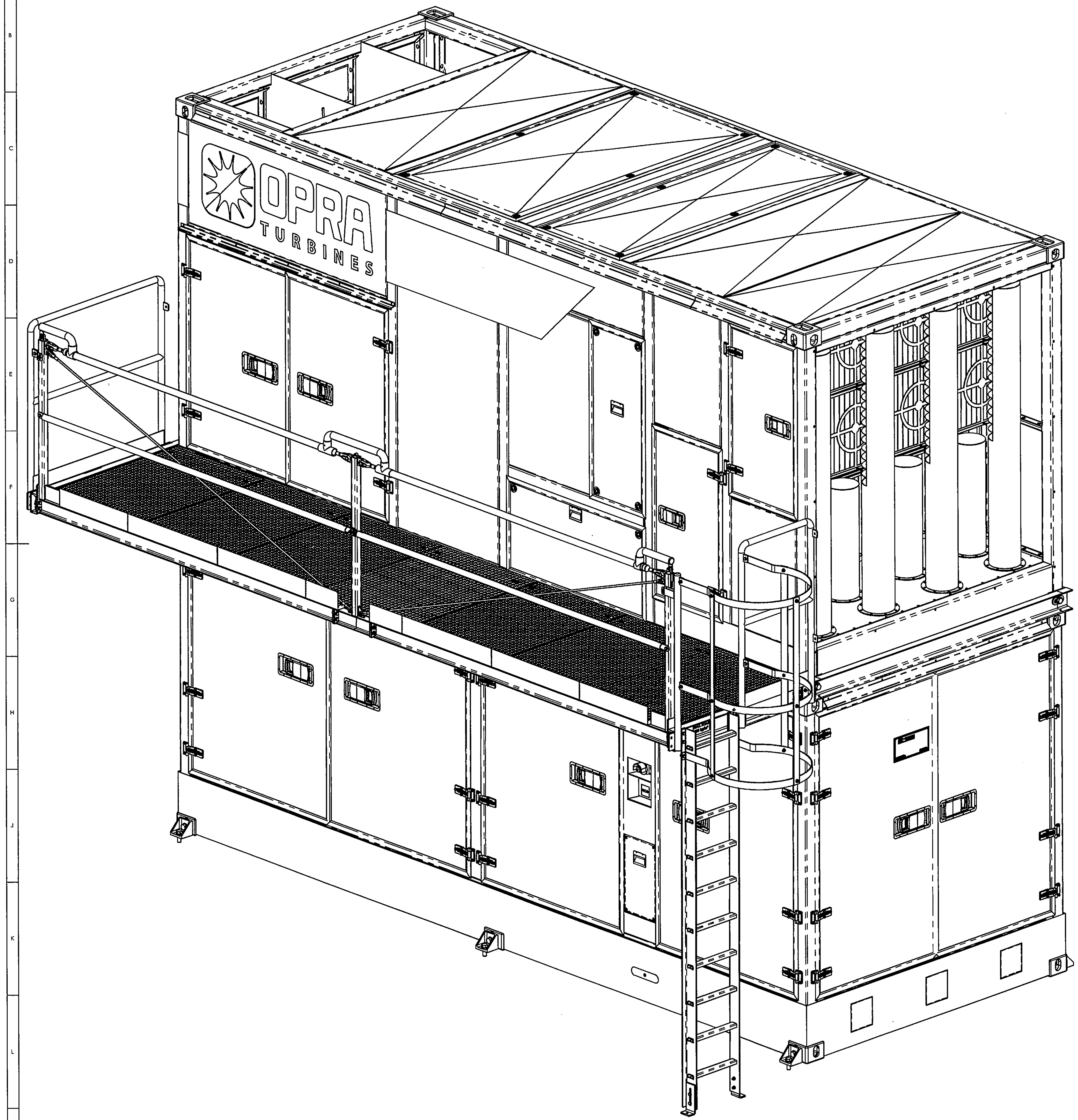
Utility grade protective relay SEL751	1	E.A.	$ 3,500.00	$ 2,500.00	100%	100%	$ 6,000
Retrofit existing switchgear with motor operators	6	L.S.	$ 3,200.00	$ 1,000.00	100%	100%	$ 25,200
Generator paralleling gear and controls	1	L.S.	$ 275,000.00	$ 45,000.00	100%	100%	$ 320,000
480 volt and 280/120 v distribution gear	1	L.S.	$ 25,000.00	$ 12,000.00	100%	100%	$ 37,000
500kW diesel generator and transfer switch	1	L.S.	$ 150,000.00	$ 45,000.00	100%	100%	$ 195,000
Northwestern Energy Direct Transfer Trip Equipment	1	L.S.	$ 15,000.00	$ 5,000.00	100%	100%	$ 20,000
Misc wiring and feeders	1	L.S.	$ 25,000.00	$ 25,000.00	100%	100%	$ 50,000
Load control system	1	L.S.	$ 75,000.00	$ 50,000.00	100%	100%	$ 125,000
Load control wiring to BAS	1	L.S.	$ 5,000.00	$ 5,000.00	100%	100%	$ 10,000
Testing/commissioning	1	L.S.		$ 40,000.00	100%	100%	$ 40,000
Electrical contigency and general conditions (mob/de-mob, general materials, etc)	15%	L.S.					$ *141,774*
TOTAL							**$ 1,086,937**

Appendix C - Turbine Equipment

ISSUE	MOD NOTE/DESCRIPTION	DATE	DRAWN BY ENGINEERING	CHECKED BY ENGINEERING	APPROVED BY ENGINEERING
A	FIRST ISSUE	28-10-2015	JGO	PGR	JHO



NOTES

GENERAL ARRANGMENT DRAWING DOES NOT IMPLY SCOPE OF SUPPLY

LEFT/RIGHT CONFIGURATION

- BOTH ENCLOSURE AND FILTRATION &VENTILATION (F & V) MODULE ARE AVAILABLE IN LEFT OR RIGHT CONFIGURATION DEPENDING ON SIDE FROM WHICH IT IS SERVICABLE (LEFT OR RIGHT, LOOKING FROM FRONT(GEARBOX END) TOWARDS REAR (EXHAUST END))

SEPARATE CONTROL CABINET

- THIS DRAWING REPRESENTS CONFIGURATION WITH SEPARATE CONTROL CABINET. THIS CABINET (SHEET 8) IS LOCATED AT PLACE SPECIFIED BY A CUSTOMER. CABINET IS HIDDEN ON MOST OF THE DRAWINGS FOR CLARITY.

WORKING PLATFORM

- LADDER SUITABLE FOR INSTALLATION ON EITHER SIDE OF WORKING PLATFORM
- WORKING PLATFORM CAN BE USED WITH EVERY TYPE OF INLET WEATHERHOOD AND CONTROL MODULE
- DESIGN LOAD FOR WORKING PLATFORM STRUCTURE : 200 KG/SQ. M
- PLATFORM COMES IN 2 DIFFERENT LENGTHS (SEE SHEET 7)

MAINTENANCE SIDE

- ENCLOSURE AND F & V MODULE CAN BE DESIGNED TO BE SERVICABLE EITHER FROM LEFT OR RIGHT SIDE ACCORDING TO CUSTOMER PREFERENCE.

FIRE FIGHTING SYSTEM

- TWO POSSIBLE FIRE FIGHTING SYSTEMS CAN BE USED:

1. INTEGRATED 3M NOVEC SOLUTION WITH EXTINGUISHING AGENT BOTTLES INTEGRATED WITHIN F & V MODULE.
2. EXTERNAL FIRE FIGHTING SYSTEM WITH CO2 BOTTLES KEPT IN A RACK LOCATED NEAR ENCLOSURE.

POWER CABLING OUTLET

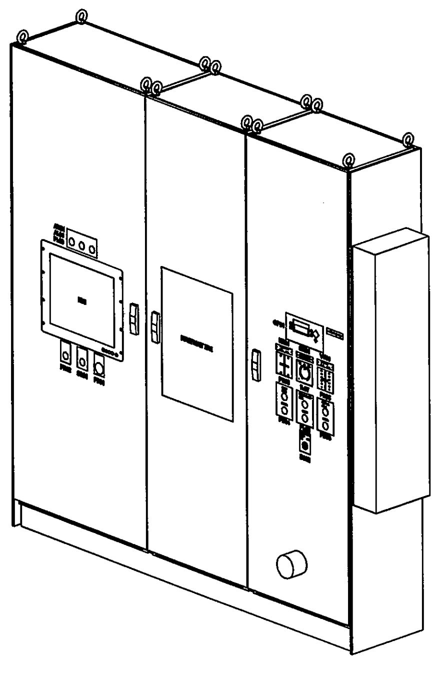
- STANDARD OUTLET FOR GENERATOR OUTLET CABLING IS VIA ROXTEC CONDUIT AT BOTTOM OF THE BASE FRAME (SEE SHEET 2). IF LOW VOLTAGE GENERATOR IS USED, SIDE OUTLET IS POSSIBLE (SEE SHEET 3).

CONTROL CABLES, CO2 PIPING, AUXILIARY AIR SUPPLY

- STANDARD INLET AND OUTLET HATCHES FOR CONTROL CABLES, CO2 PIPING AND AUXILIARY AIR SUPPLY ARE EITHER VIA 3 FRONT HATCHES (SEE SHEET 4) OR VIA 3 HATCHES LOCATED AT BOTTOM OF BASE FRAME (SEE SHEET 2)

DIMENSIONS

- DIMENSIONS IN MILLIMETERS (INCHES IN SQUARE BRACKETS)



PREVIOUS No.	USED ON
-	-

UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS ARE IN mm

SURFACE TEXTURE TO BE 3.2 MICROMETERS IN ACCORDANCE WITH: ISO 1302
GENERAL TOLERANCE: ISO 2768

DO NOT SCALE DRAWING

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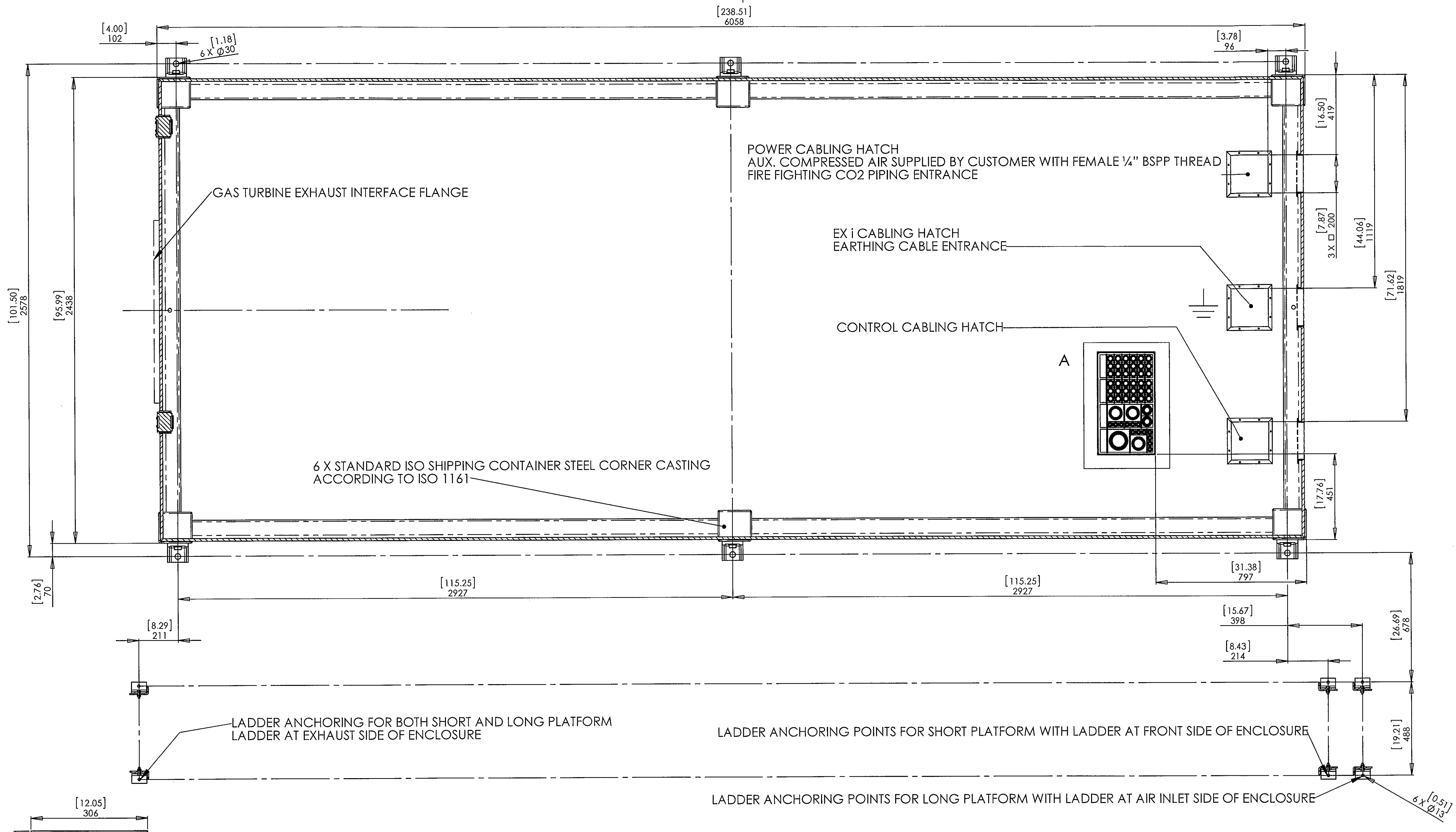
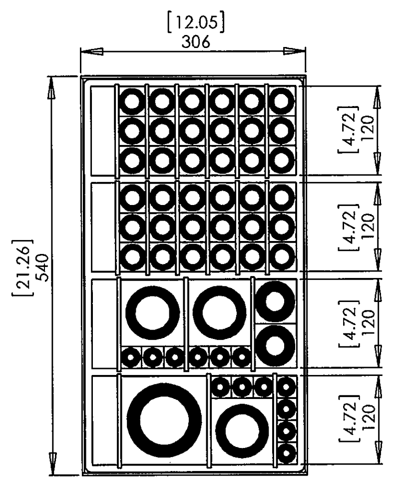
TITLE: GA SEPARATE CONTROL CABINET

PROJECTION	DRAWING No.	ISSUE
	7024565	A
	SCALE 1:50	SHEET 1 OF 8



FOOTPRINT (TOP VIEW)



DETAIL A
SCALE 1 : 5

-STANDARD GENERATOR OUTLET ROXTEC CONDUIT

-FINAL ARRANGEMENT OF CONDUIT DEPENDS ON POWER OUTLET CABLE TYPE

NOTE

- TO BE READ TOGETHER WITH OPRA SPECIFICATION : FOUNDATION RQUIREMENTS FOR 20 FT CONTAINER PACKAGE

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SCALE	DRAWING No.	ISSUE	SHEET
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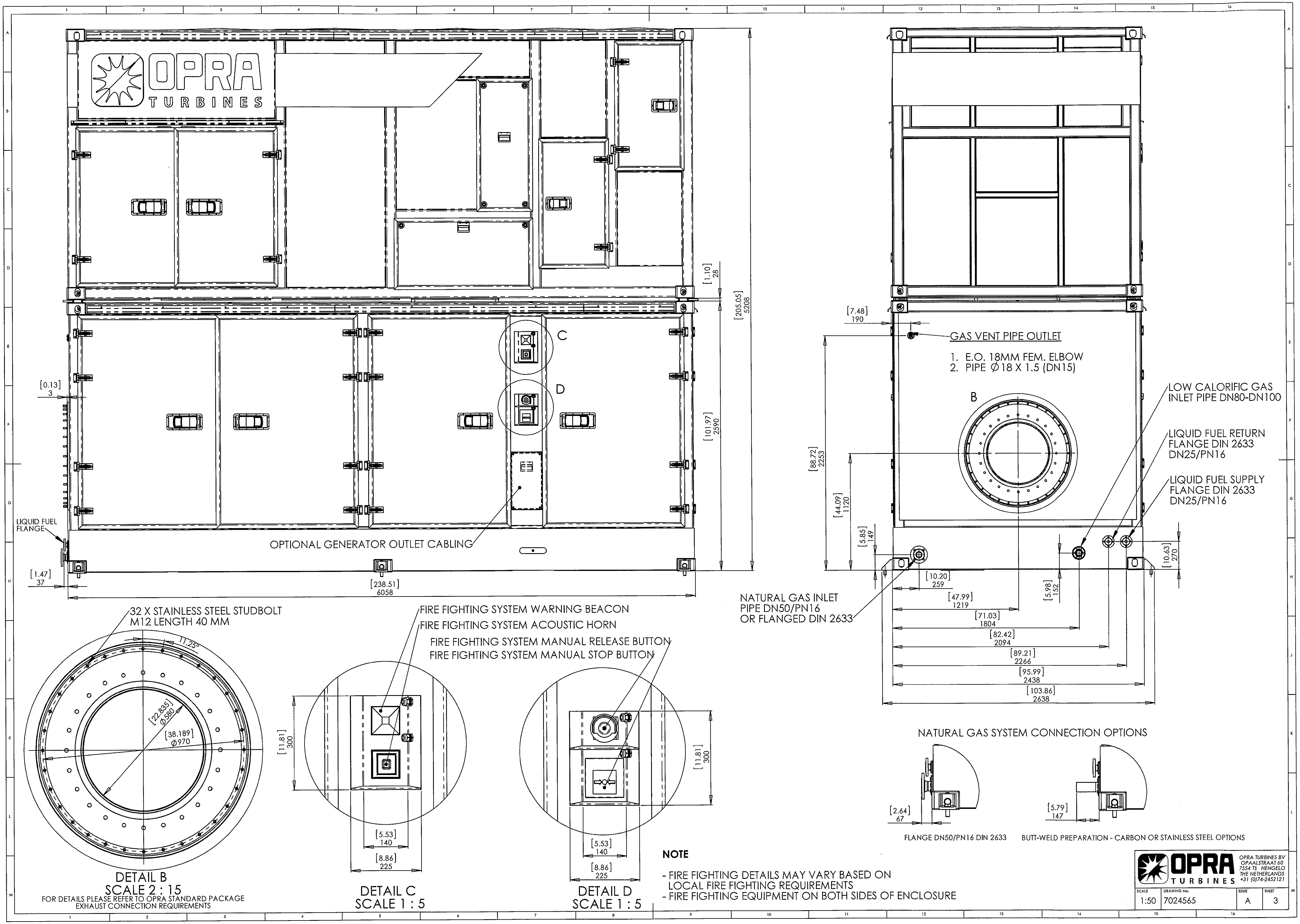
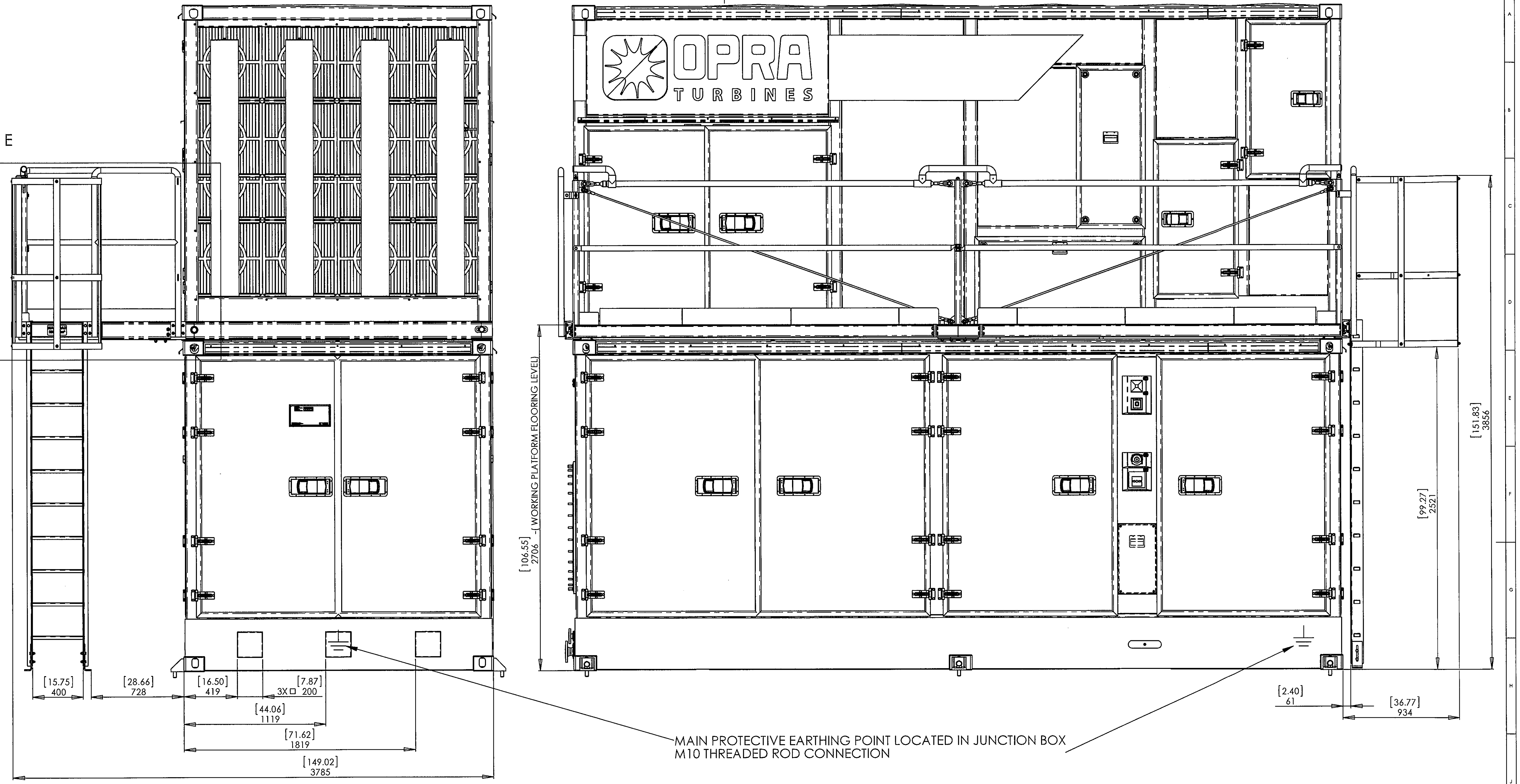
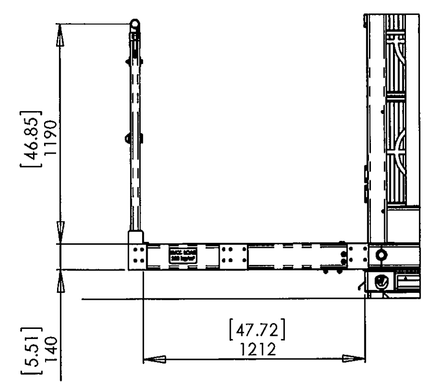


NOTE

- FIRE FIGHTING DETAILS MAY VARY BASED ON LOCAL FIRE FIGHTING REQUIREMENTS
- FIRE FIGHTING EQUIPMENT ON BOTH SIDES OF ENCLOSURE



CONNECTION DIMENSIONS FOR CUSTOMER PLATFORM
(HANDRAIL AND OTHER ITEMS HIDDEN FOR CLARITY)



DETAIL E
SCALE 1 : 20

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SCALE	DRAWING No.	ISSUE	SHEET
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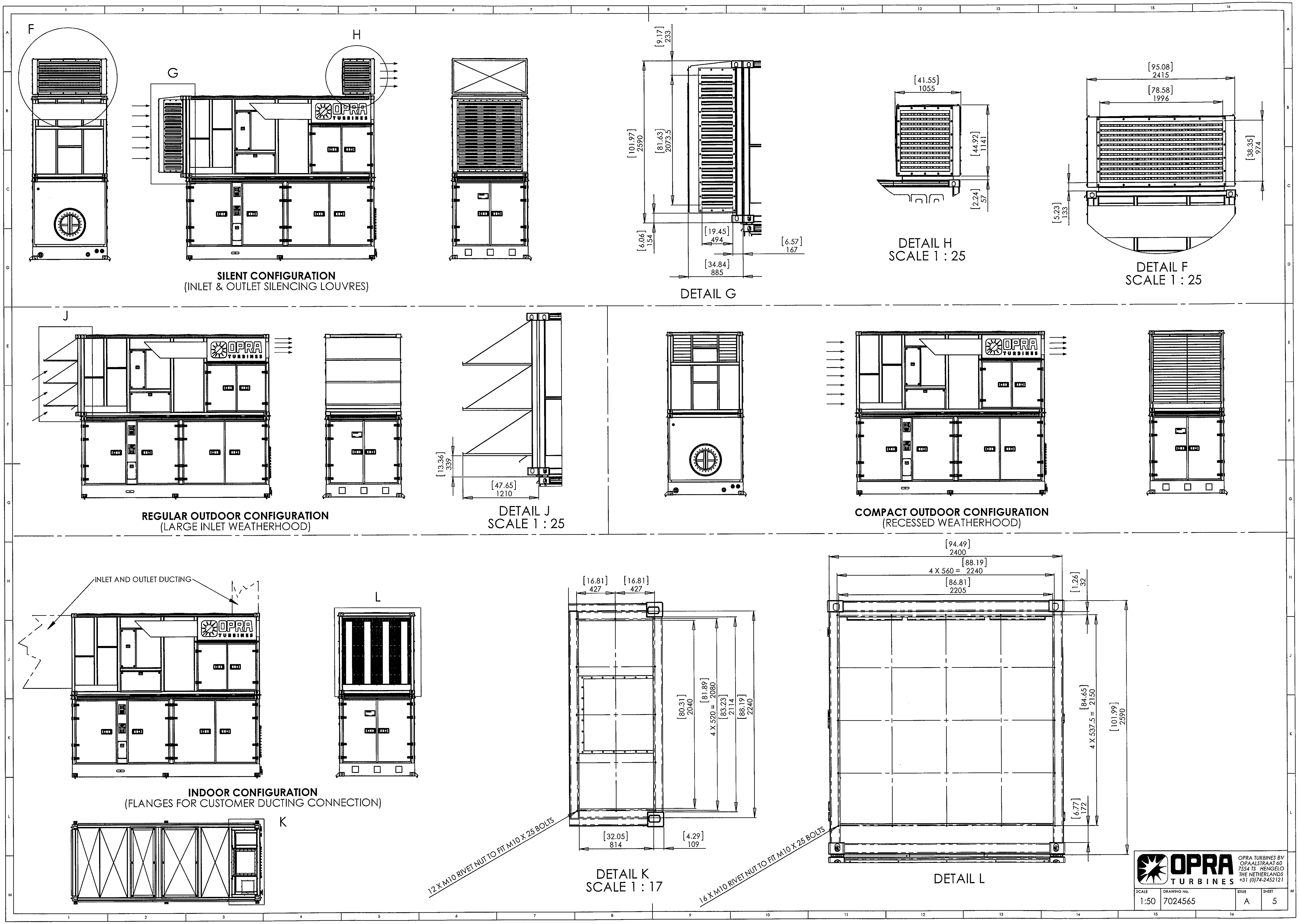

F
G
H
SILENT CONFIGURATION
(INLET & OUTLET SILENCING LOUVRES)
[9.17] 233
[101.97] 2590
[81.63] 2073.5
[6.06] 154
[19.45] 494
[6.57] 167
[34.84] 885
DETAIL G
[41.55] 1055
[44.92] 1141
[2.24] 57
DETAIL H
SCALE 1 : 25
[95.08] 2415
[78.58] 1996
[38.35] 974
[5.23] 133
DETAIL F
SCALE 1 : 25
J
[13.36] 339
[47.65] 1210
DETAIL J
SCALE 1 : 25
REGULAR OUTDOOR CONFIGURATION
(LARGE INLET WEATHERHOOD)
COMPACT OUTDOOR CONFIGURATION
(RECESSED WEATHERHOOD)
INLET AND OUTLET DUCTING
L
INDOOR CONFIGURATION
(FLANGES FOR CUSTOMER DUCTING CONNECTION)
K
[16.81] 427
[16.81] 427
[80.31] 2040
[81.89] 4 X 520 = 2080
[83.23] 2114
[88.19] 2240
[32.05] 814
[4.29] 109
12 X M10 RIVET NUT TO FIT M10 X 25 BOLTS
DETAIL K
SCALE 1 : 17
[94.49] 2400
[88.19] 4 X 560 = 2240
[86.81] 2205
[1.26] 32
[84.65] 4 X 537.5 = 2150
[101.99] 2590
[6.77] 172
16 X M10 RIVET NUT TO FIT M10 X 25 BOLTS
DETAIL L
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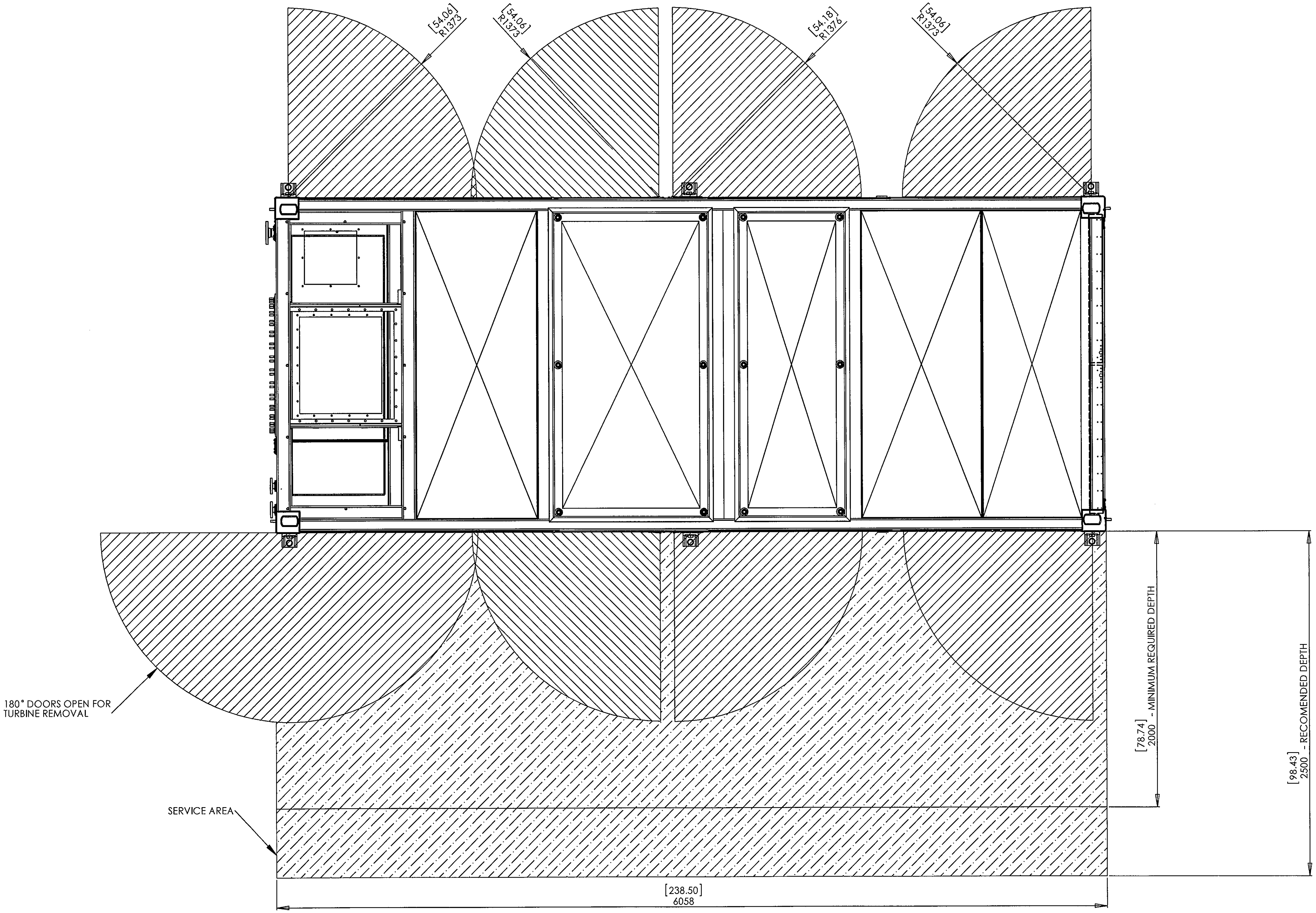
SCALE 1:50
DRAWING No. 7024565
ISSUE A
SHEET 5

TOP VIEW



BOTH ENCLOSURE AND F&V MODULE ARE SERVICABLE FROM ONE SIDE ONLY DEPENDING ON CUSTOMER PREFERENCE (LEFT OR RIGHT CONFIGURATION)

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SCALE	DRAWING No.	ISSUE	SHEET
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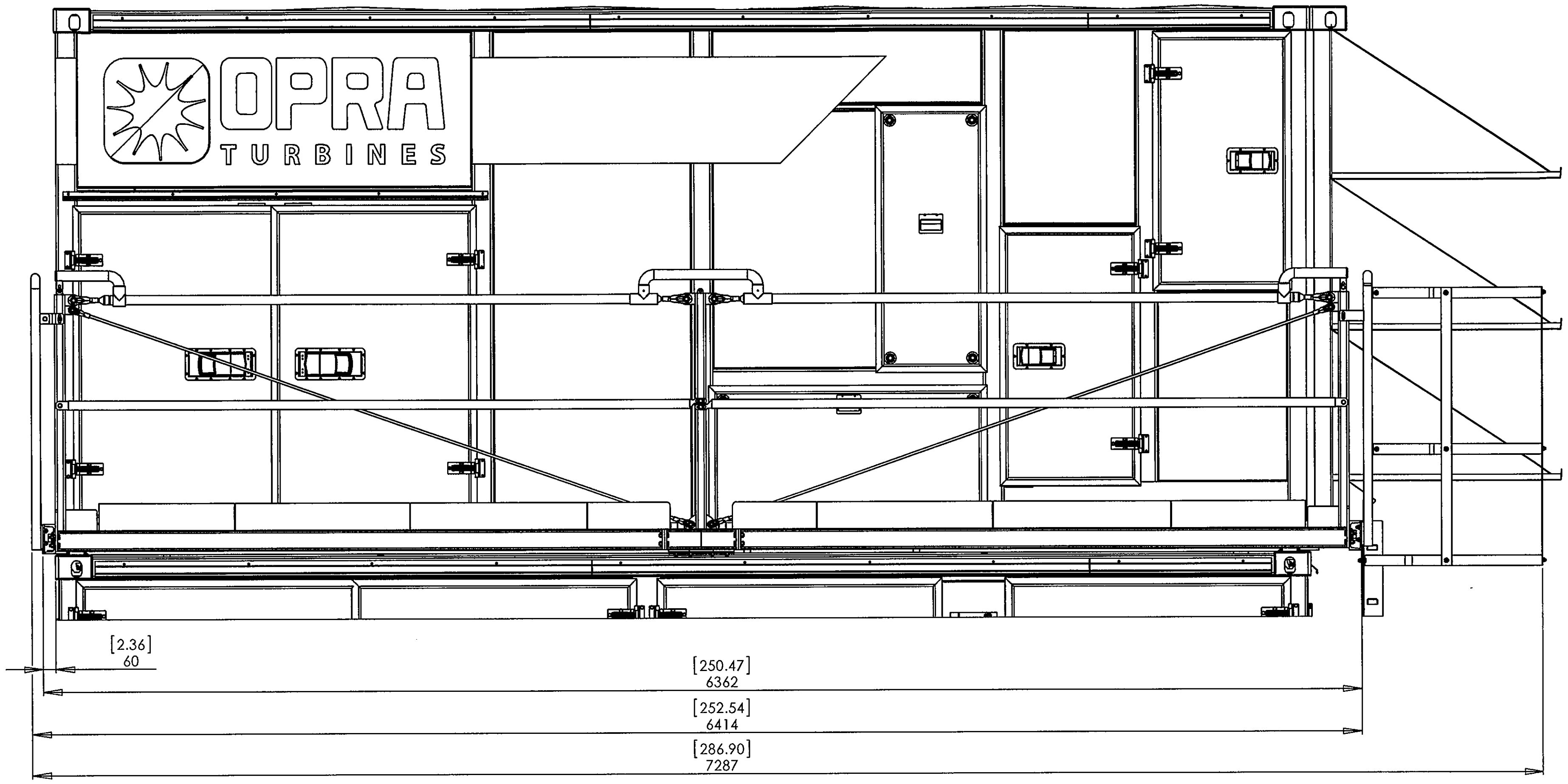
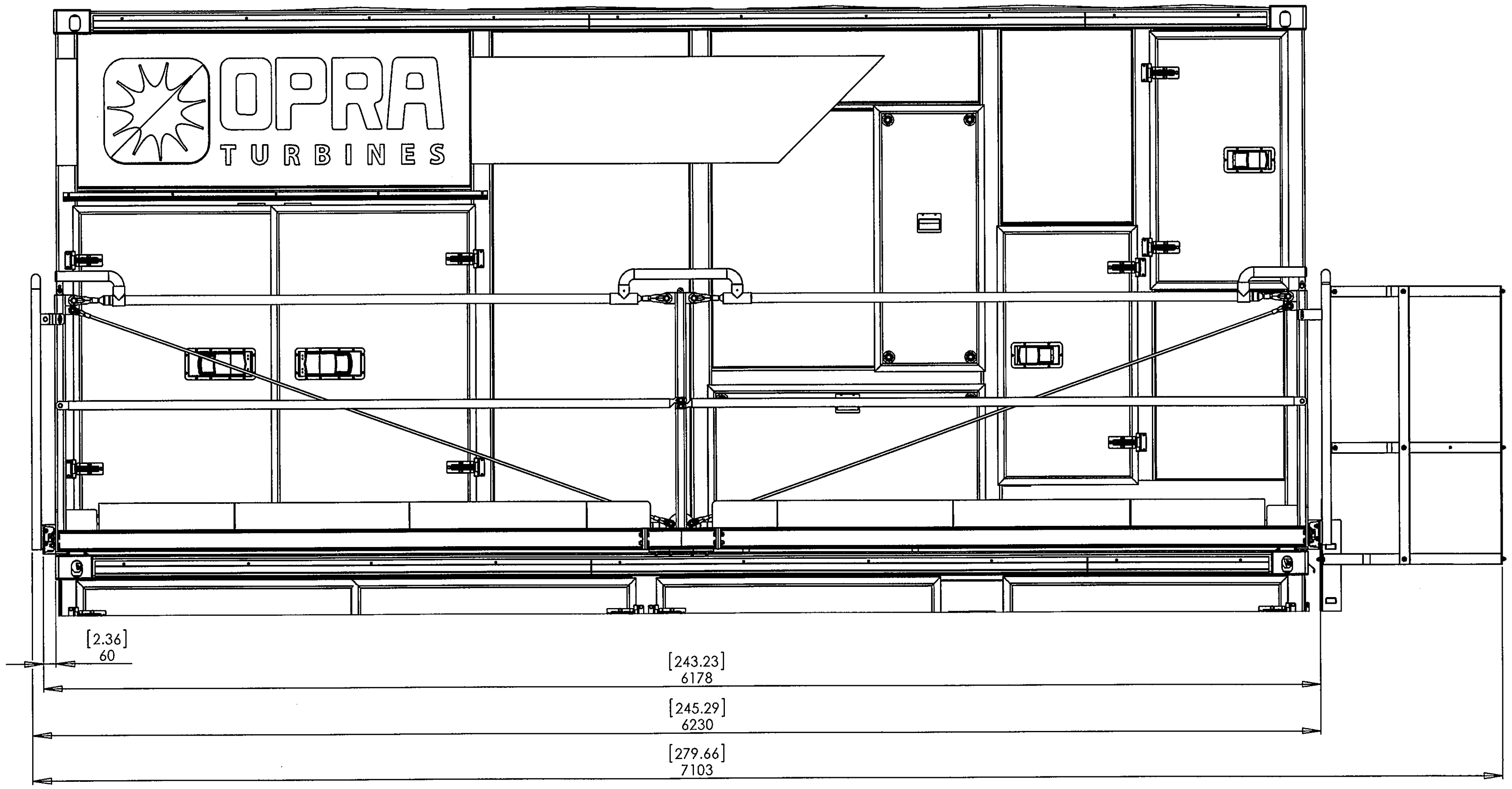


LONG PLATFORM DESIGN - TO BE USED TOGETHER WITH LARGE INLET WEATHERHOOD AND INLET SILENCING LOUVRES



SHORT PLATFORM DESIGN - TO BE USED TOGETHER WITH RECESSED WEATHERHOOD AND IN CASE OF INLET DUCTING UTILIZATION

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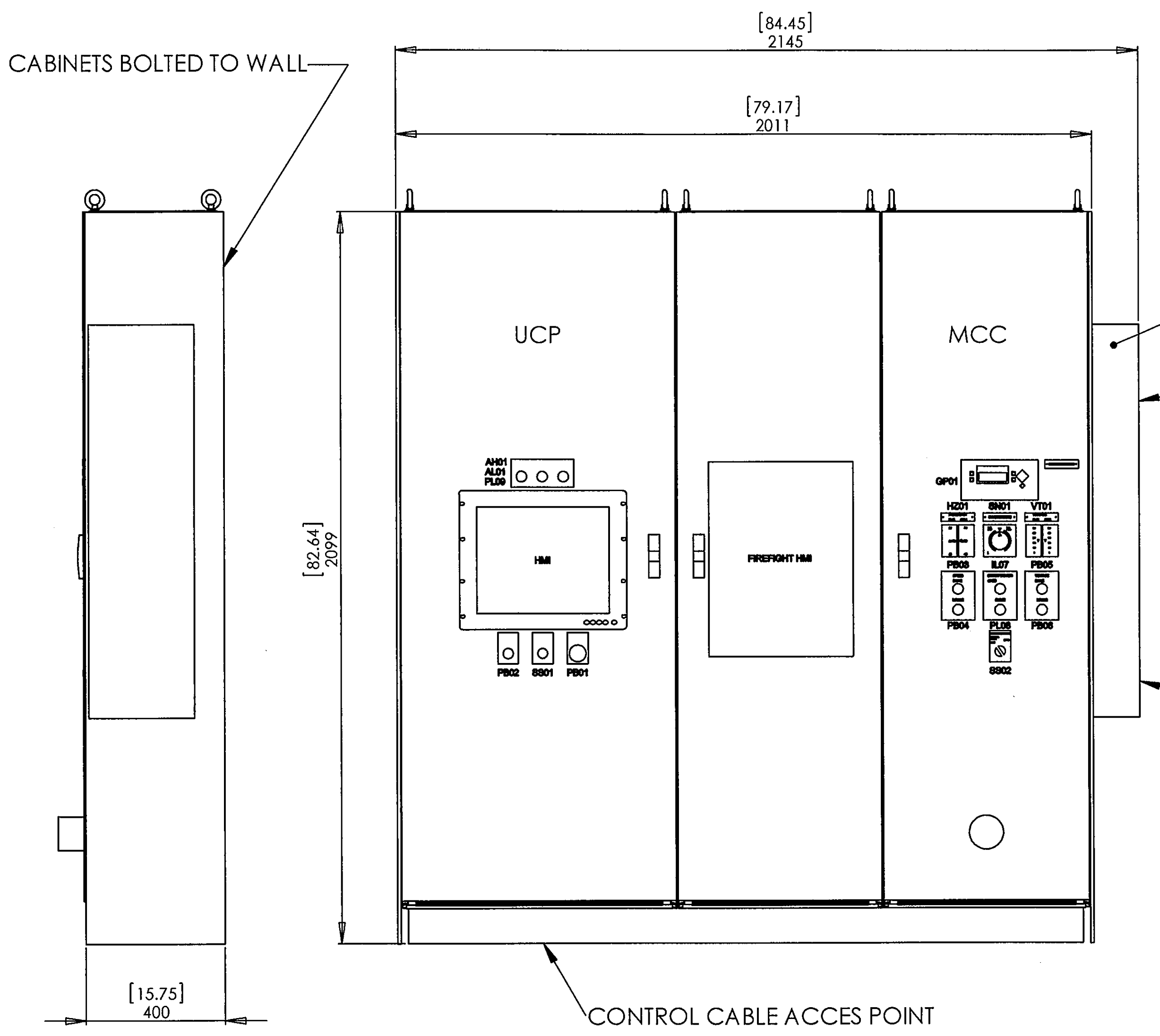
SCALE	DRAWING No.	ISSUE	SHEET
1:50	7024565	A	7

SEPARATE CONTROL CABINET - RIGHT CONFIGURATION

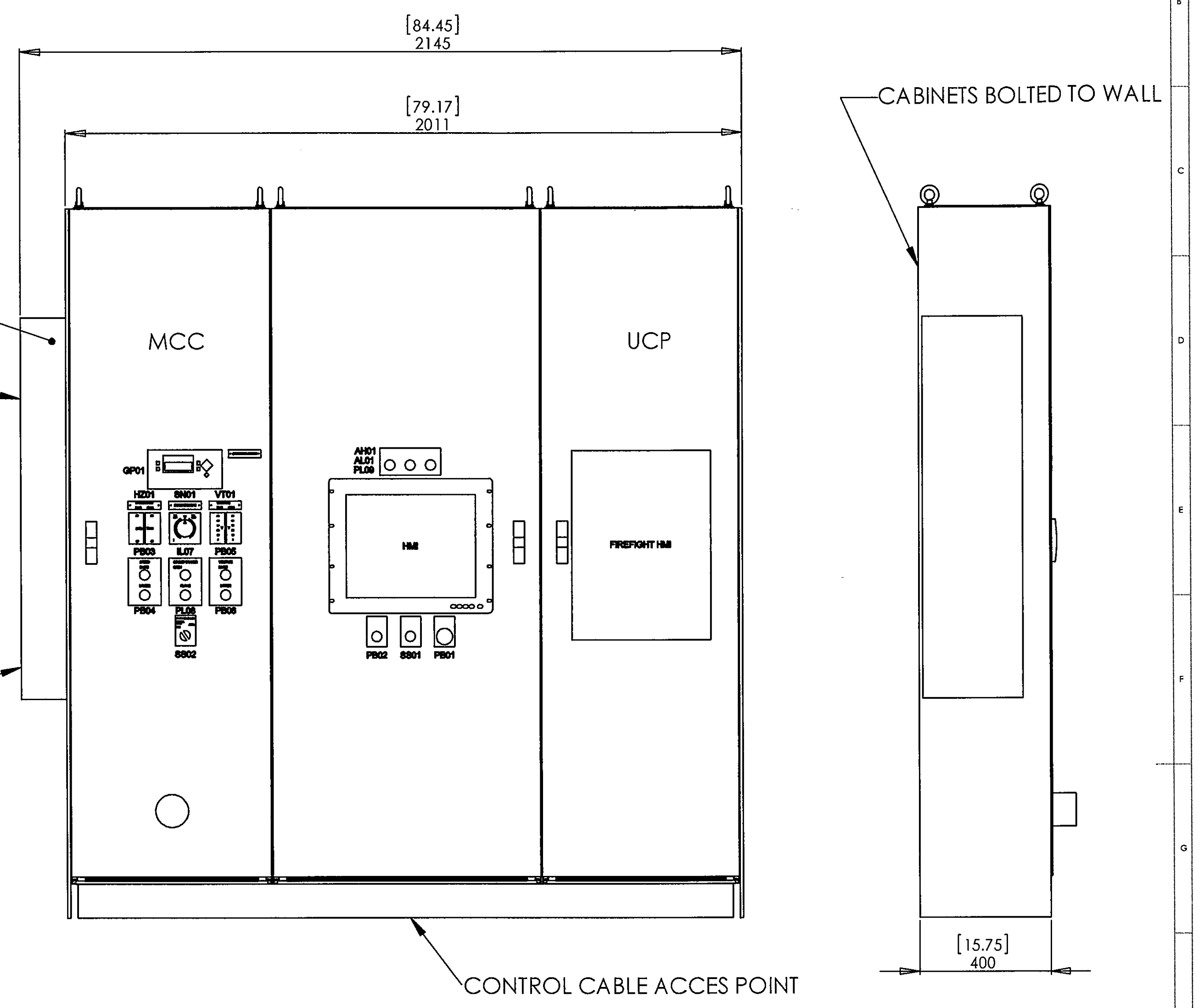


AIRCO-UNIT

AIR OUTLET

AIR INLET

SEPARATE CONTROL CABINET - LEFT CONFIGURATION



FOOTPRINT OF CABINETS IN TOTAL 400MM X 2000

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SCALE	DRAWING No.	ISSUE	SHEET
1:10	7024565	A	8

BUDGET QUOTATION

-Commercial section-

Rev. 1.0

FOR

CTA Architects Engineers

Project reference	**2016-0095 CTA Architects Engineers**
Proposal request date:	**11 October 2016**
Proposal issue date	**20 October 2016**
OPRA contact	**Anshuman Pandey**

Tel. **: +31 6211 54093**

E-mail **: a.pandey@opra.nl**

1. OP16 gas turbine generating set budget price

The budget price for two (2) OP16-3B Turbine Generating set as described in this proposal is

$ 3,557,000,=

FCA Hengelo (The Netherlands) according to Inco terms 2010.

The scope includes the engineering, fabrication, and testing of all equipment detailed in the Scope of Supply (13.8kV generator package).

Options

No.	Item	Price
1	3B Dual Fuel	$ 112,000 per genset
2	Arctic Package	$ 55,500 per genset
3	Weather Hoods	$ 44,200 per genset

Payment Terms

Installments:

1. 40% pre-payment on order confirmation.
2. 60% on readiness to ship but before shipment.

Delivery date

Delivery excludes transit time and is defined as the date on which the key equipment leaves OPRA premises in Hengelo, The Netherlands.

- Delivery of OPRA key equipment is 10 months after 40% down payment.

Validity

This budget quotation is valid until 11 November 2016.

Terms & Conditions

OPRA's standard terms & conditions apply.

Confidentiality Statement

This document contains confidential information and is not to be divulged to any third party without first obtaining prior written permission of OPRA.

BUDGET QUOTATION

-Technical section-

Rev. 0

FOR

CTA Architects Engineers

Project reference	**2016-0095 CTA Architects Engineers**
Proposal request date:	**11 October 2016**
Proposal issue date	**11 October 2016**
OPRA contact	**Anshuman Pandey**

Tel. **: +31 6211 54093**

E-mail **: a.pandey@opra.nl**

Contents

OPRA Gas Turbine

1. Introduction

The OPRA generator set is powered by a reliable, economical OP16 all-radial industrial gas turbine unique in its power range. As an industrial turbine, it is designed from the outset to provide long life and high reliability for continuous duty electrical power generator applications. The single shaft configuration is particularly suited to constant speed generator loads. The compressor and turbine are integral in design, with all bearings and bearing supports in the cold section of the engine for extended bearing and lubricating oil life. Oil consumption is negligible with the overhung rotor configuration.

Figure 1: Compressor and rotor in an integral design with an overhung configuration

OPRA gas turbines are simple, efficient and robust multi fuel power plants of nominally 2 MW power per unit, applicable for installations up to 10 MW plant size. Specific features of the OP16 units are as follows:

- As the bearings are located in the cold section of the turbine shaft, oil consumption is virtually zero. This enables OPRA Turbines to provide a very friendly maintenance schedule with a time between overhaul of 42,500 hours.
- A radial inflow turbine with 700 m/sec (2297 ft/sec) tip speed, receives hot combustion gases at a similar velocity via guide vanes. With essentially no difference between the two velocities the turbine tips will avoid the stagnation temperature. This could mean a reduction in turbine temperature of 100°C (180 °F) compared to an axial turbine installation.
- The turbine cross section has an “Eiffel Tower” configuration with a strong base and relatively thin and light blade tips, enabling a high tip speed without extreme stress levels.
- The robust radial turbines are insensitive towards small changes in turbine geometry caused by foreign objects. Axial turbines could easily loose performance under similar circumstances.
- The radial turbine performance is enhanced by an exhaust diffuser, starting at sub atmospheric conditions and ending up at ambient conditions at the exhaust outlet.

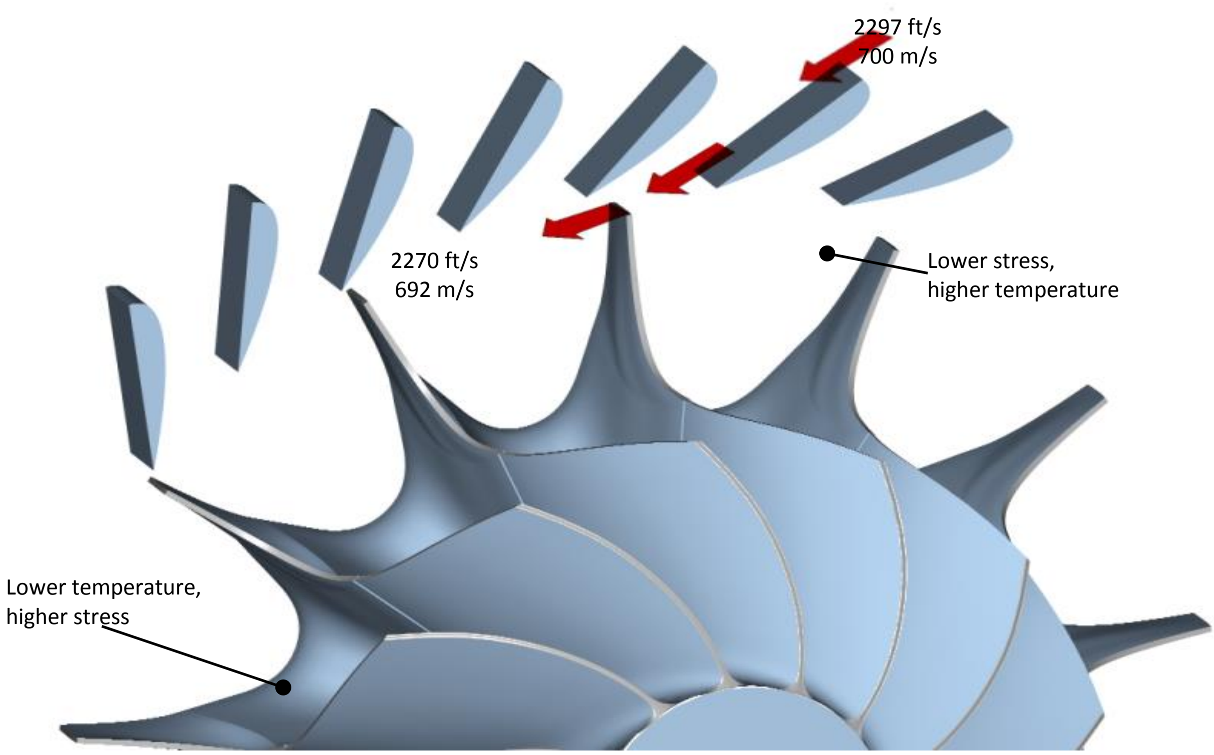


Figure 2: OPRA's "Eiffel Tower" turbine

- The compact centrifugal compressor / radial turbine enable bearings to be placed in front of the compressor in a cantilevered position. This greatly improves the cooling of bearings and reduces lube oil consumption to practically zero.

- The OP16 pressure ratio is relatively low; 6.7/1. This reduces the power needed to compress the fuel when gas is used.

- OPRA's can combustors have great advantages compared to, for example, engine systems with annular, multi nozzle arrangements. Such systems are more sensitive to fuel quality and fuel variations compared to the OPRA can system. In addition, combustion can inspections and replacement can be readily accomplished without disassembly of the engine.

- OP16 turbines are available with combustors that will provide ultra low emissions NOX, in addition to versions burning low calorific fuels

- Despite the simplicity of the OP16, this turbine engine has the lowest fuel consumption in its power class.

- The OP16 is equipped with a compact proprietary planetary reduction gear enable to fit both 50 and 60 cycle applications.

The rotor assembly operates at 26,000 rpm and an integral gearbox reduces the rotor speed to 1500 / 1800 rpm for synchronous generator 50 / 60 Hertz frequencies. The gearbox also contains the main lubrication pump drive and the starter input drive.

The turbine's four reverse flow combustor cans distribute the hot combustion gases evenly to the turbine inlet guide vanes. The OP16 is available for operation on liquid fuel, natural gas fuel or dual fuel supplies. As a dual fuel unit, the turbine can switch seamlessly from liquid to gas and back under load. The turbine operates over a wide range of gaseous fuels, with heat content ranging from natural gas down to landfill or biomass fuels.

The turbine wheel receives combustion gas tangentially through the turbine inlet guide vanes and discharges exhaust gas axially along the centerline of the engine. The axial exhaust configuration provides excellent diffusion performance and is ideal for ducting the exhaust heat of into any waste heat recovery system.

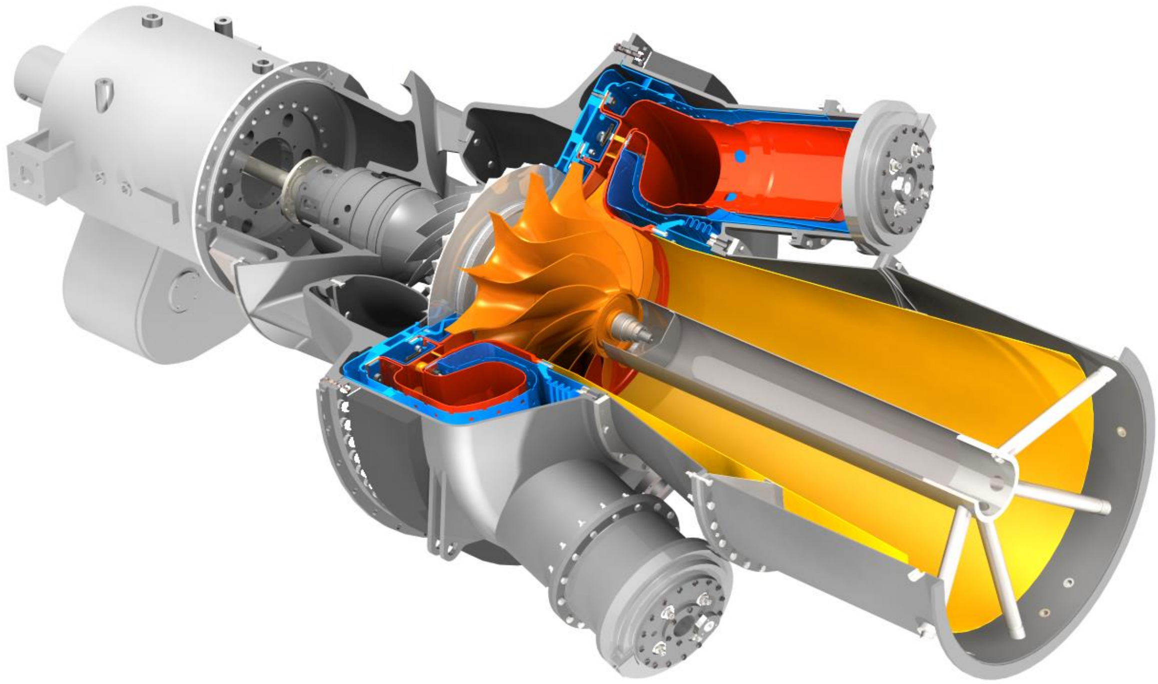


Figure 3: Simple, robust and reliable, all radial type gas turbine of OPRA

A fabricated structural steel base assembly incorporates the turbine lubricating oil reservoir and various auxiliary systems such as starting system, oil system, fuel system and generator. The base permits for the turbine generator set to accommodate installation variations and to be quickly installed on a concrete pad or platform deck without the need for too advanced alignment or grouting. The base coating system is suitable for indoor or outdoor installation and can be provided with additional corrosion protection for marine environments.

AC motor-driven variable displacement hydraulic pump provides turbine-starting power through an axial-piston starting motor mounted on the reduction gear. The lubricating oil system includes a gear-driven main pump, motor driven auxiliary (pre/post-lube) pump, duplex oil filters, temperature control valve and oil cooler with electric motor driven fan.

The standard generator is normally an open drip proof 4-pole, 3-phase synchronous self ventilated generator with built-in exciter. Generators are available to meet customer specifications as they relate to enclosure, temperature rise, insulation class and bearing lubrication.

A control panel for indoor installation involving solid state logic provides start-up and shut-down sequencing, speed governing, engine protection, generator protection, generator synchronizing, alarm and status indication and the operator control interface. The control panel can be loose shipped for remote indoor installation or fully prewired to the skid and installed in an on-skid control room.

2. OP16 gas turbine generating set specifications

Turbine: OP16-3B industrial single-shaft, all-radial gas turbine, rated 1850 kWe at ISO conditions.

Generator: Synchronous Generator, Brushless type, 4-pole, 60Hz, 3-phase, 2313 kVA @ 15 °C (59 °F), 1800 RPM, open drip-proof construction (IP23). Generator comes default with a floating star point. 0.8 lagging power factor, 0.9 leading power factor.

Area classification: Equipment will be installed in a non-hazardous zone. The OP16 package is over-pressurized with the air intake installed in a non-hazardous area.

Dimensions and weight: 6810 mm (22,4 ft) long x 2440 mm (8 ft) wide x 5209mm (17 ft) high approximately 28 metric tonnes (48,500 lbs). These weight and dimensions are based on a 400V generator and include control panels on a skid extension, air filtration and ventilation module, but exclude an exhaust system.

Site conditions: Ambient temperature range from -20 to +86°F with an average annual temperature of 59°F, site elevation 3200ft above sea level. Turbine package will be installed indoor.

Emissions: The OP16-3B gas turbine generating set is equipped with dry low emission system for ultra-low exhaust emissions:

Temp:	@ 15°C, 15% O2	@ 15°C, 15% O2
CO	< 60 [ppmv]	< 75 mg/Nm^3
NO_x	< 30 [ppmv]	< 59 mg/Nm^3

OPRA ultra low emissions table @ 70 – 100% load

Backpressure: A lower backpressure of the exhaust system (i.e. boiler) is advantageous for the electrical efficiency and general lifetime of turbine components. The OP16 operates with the following backpressures of the OP16 exhaust:

- Nominal: 2.5kPa
- Alarm: 3.5kPa
- Trip level: 5.0kPa.

Operating principles:

- Connected and synchronized to the grid;
- Normal starting time from standby mode to full power: 200s. This excludes the grid synchronization time and the time needed to purge the exhaust system (i.e. boiler);
- The all-radial OP16 gas turbine is able to run at any electrical load between 0 – 100%;
- When operating in island mode, the OP16 is able to make 1.5MWe load steps;
- Cos Phi compensation on grid connection point within the operational boundaries of the generator following a remote set-point signal is possible.

Service area: The service area, when looking from the generator side to the exhaust side of the turbine enclosure, will be either on the left or right side depending on site conditions.

Fuel specifications: Dry clean natural gas, properties in accordance with the attached Utility list in Appendix A.

3. OP16 gas turbine generating set scope of supply

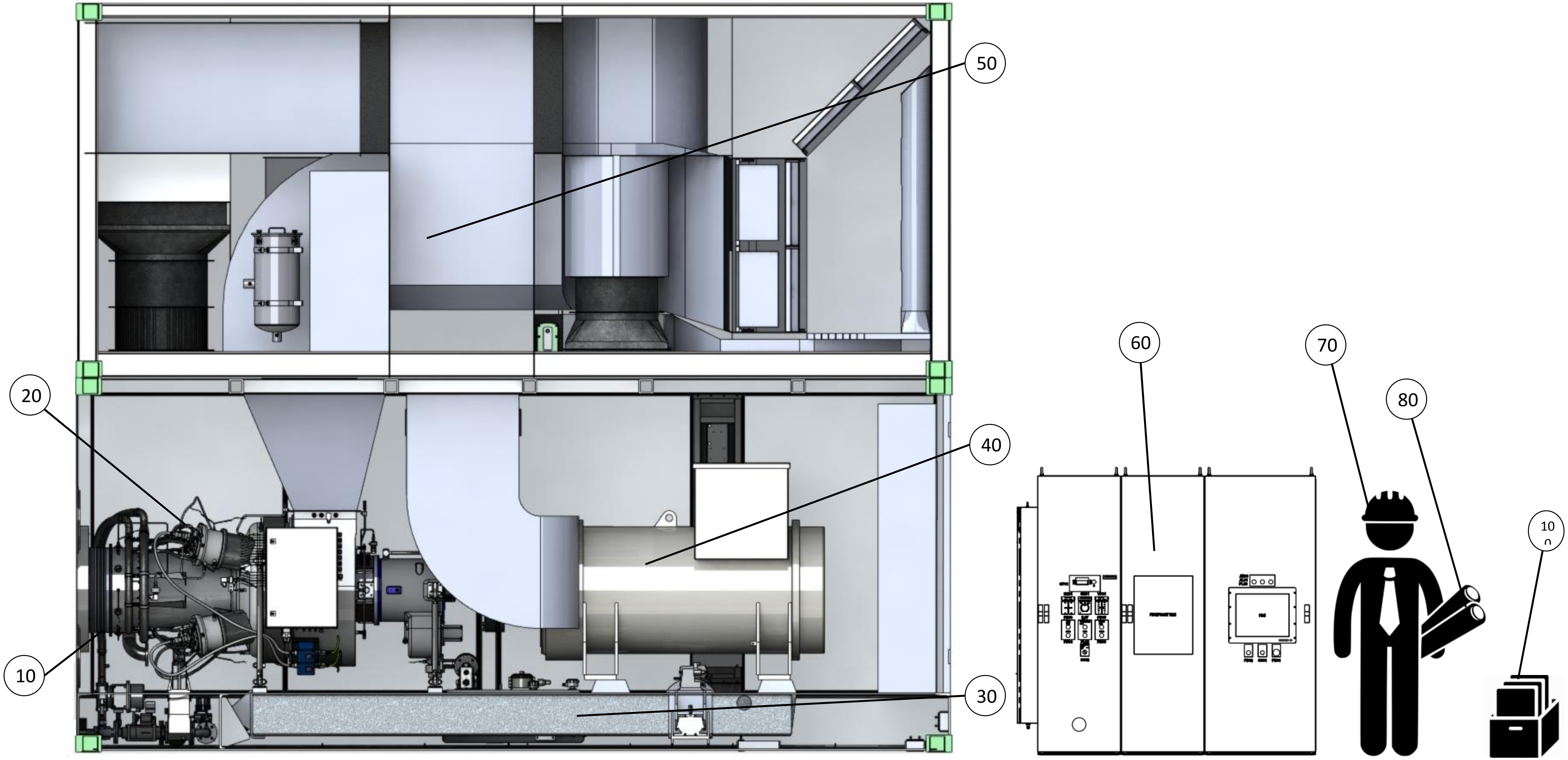


Figure 4: Breakdown of OP16 system components

10 OP16 Gas Turbine engine	40 Electrical Generator	70 Installation & commissioning	100 Documentation
20 Combustion system	50 Air filtration and ventilation	80 Engineering and training services	
30 Enclosure and support systems	60 Control system	90 Certification and government approvals	

3.1 Specification of scope of supply

Pos.	Component	Description	OPRA Scope: Included	Optional	Excluded
10	**OP16 Gas Turbine engine**				
	OP16 gas turbine engine	OP16 all-radial industrial gas turbine designed for simplicity, ruggedness and durability, rated 1.85MWe at ISO conditions. Single shaft configuration with bearings and supports located in the engine's cold section. Single stage centrifugal compressor with a moderate 6.7/1 compression ratio offering a high flow path efficiency. Insulated AISI 316 exhaust diffuser. Core engine weight is ±1700kg and 2500mm x 1500mm x 1500mm.	X		
	Integrated reduction gearbox	OPRA proprietary design, Swiss manufactured 2-stage epicyclical configuration speed reduction gearbox to reduce speed from 26,041 rpm turbine RPM to 1500 rpm (50 Hz) or 1800 rpm (60Hz) on the output shaft to the generator. Shear pins located on the output shaft for overload protection.	X		
	Flexible coupling	KTR G200 HE T52ShA OPRA standard flexible drive gearbox and generator coupling safeguarded by a totally enclosed coupling guard.	X		
	Flame monitoring system (Optical flame monitoring system can be provided on request)	2 thermocouples per can combustor confirming ignition and presence of a combustion flame.	X		
20	**Combustion system**				
	OP16-3B Dry Low Emissions (gas fuel only)	➢ 3B low emission premixed combustion system. ➢ Gaseous fuel system with stainless steel gas system piping equipped with pressure and temperature transmitters. Cellular filter with a pressure differential switch. Failsafe pneumatic double block and bleed valves system, 3B fuel metering system, bleed air system, 4 gas fuel nozzles and a control system upgrade for DLE equipment.	X		
30	**Enclosure and support systems**				
	OP16 gas turbine enclosure	➢ Three-point anti-vibration mounted subskid inside heavy structural base frame. Base frame is mounted on a foundation following the requirements detailed in Appendix D. ➢ Enclosure walls receive an outside protection level 1 surface treatment consisting of a 2 layer coating (Intercure 200HS and Interthane 870). Suitable for atmospheres with temperatures up to 120°C. Enclosure and control room walls are insulated with 2 layers of mineral wool covered with perforated sheet. Enclosure rated IP54. Average turbine enclosure noise pressure emissions are attenuated up to 80 dBa @ 1m (free field conditions), sound power level 100dBa.	X		

Pos.	Component	Description	OPRA Scope: Included	Optional	Excluded
	Firefighting system (NOVEC can be offered on customer request)	Consists of manual release button outside the enclosure, alarm signals, two flame detectors, two heat detection sensors, piping, valves, mechanical actuator(s), electrical actuator(s), pressure switches and spray nozzles to effectively fill the enclosure with CO_2 fire extinguishing agent. Two bottles containing the extinguishing agent are located in a bottle rack. The firefighting system requires a separate power supply to be provided by CUSTOMER.	X		
	Oil system	➢ Lubrication oil system has a stainless steel, oil tank containing 200 liters of ISO32 grade lubrication oil, provided with level transmitter. Standard 2.4kW lube oil tank heaters have thermostatic temperature control to ensure the right viscosity and oil temperature in case of system standstill. The lube oil system further consists of an engine driven oil pump, suction filters, distribution block, AC motor driven auxiliary pump, oil piping and hoses. The oil demister integrated in the ventilation module reduces oil mist emissions into the environment to virtually zero. The duplex type lube oil filter with internal by-pass valve and manual changeover and the air-oil lube oil cooler including cooler matrix, AC motor, fan, fan guard and fan housing with a nominal capacity of 65 kW cooling capacity are mounted inside the OP16 enclosure to: 1. Prevent spilling of oil to the environment as the OP16 base frame is designed to contain all lube oil in case of a leakage, and 2. As filtered air is used in the oil cooler, fouling of the cooling fan is prevented and a more constant cooling capacity is guaranteed. ➢ The starting system consists of a hydraulic starter pump driven by an electric motor, pressurizing lubrication oil driving the hydraulic starter motor mounted on the gearbox. The starting system starts the turbine until reaching the self-sustained 26,041 rpm speed, and purges the exhaust system prior to the starting sequence at purge speed.	X		
	Gas detection	To avoid gas accumulation in case of gas leakage, the turbine enclosure is provided with two infrared gas detectors located at the ventilation outlet and inside the enclosure. The sensors are connected to the safety system.	X		
	Compressor washing system	The compressor washing system removes most of the contaminants creating compressor fouling. The system consists of a 20-liter water tank, a pressure gauge, pressure-relief valve, filter and compressor washing system quick couplings.		X	
	Platforms and ladder	Platforms with ladders for safe access to the equipment located inside the air filtration and ventilation module. Maximum weight 200kg/m2.		X	

Pos.	Component	Description	OPRA Scope: Included	OPRA Scope: Optional	OPRA Scope: Excluded
	Special tools	Set of special tools to be able to perform maintenance on the generator and turbine. Special tools set includes a gearbox turning tool, oil heater spanner, OP16 engine lifting frame, engine support frame and engine transportation frame, gearbox shear pin tool, gearbox seal fitting tool, coupling tool, gearbox seal replacement tools, gearbox guide pins tooling, shaft rotation tool and an alignment tool.		X	
40	**Electrical generator**				
	13.8kV Standard generator	Synchronous generator 13.8V, 60 Hz, 2313 kVA @ 15°C (59°F) (0.8 lagging power factor, 0.9 leading power factor), open drip proof, protection class IP23, roller bearings. Temperature rise class F. Insulation class H. Generator weight ±8000kg.	X		
50	**Air inlet, filtration and ventilation**				
	Air inlet system	The air inlet system treats the air coming through the 4.6 m^2 inlet screen and directs the air partially to ventilate the enclosure and partially to the OP16 for the engine combustion process. The air inlet module consists of the following standard components: ➢ Filter house made of carbon steel (S235) with integrated carbon steel inlet ducting leading to enclosure ventilation and combustion air inlets. The filter house contains sound dampers to attenuate average sound levels to 80 dBa @ 1m (3ft) (free field conditions). ➢ Two inlet ventilation fans with G4 filter elements filters air going through the enclosure ventilation system and creates a slight over pressure in the turbine enclosure. The ventilation system is used to ventilate the enclosure, blow out the radiation heat from the turbine/generator and to remove gas from possible gas leaks. The oil cooler is also using this ventilation air stream. ➢ Also integrated in the air inlet system is a separate turbine combustion air filtration system, of a two-stage G4 and F9 air filter configuration. ➢ The OP16 anti-icing system recirculates the generator cooling air and air from the oil cooler to the air inlet filters heating the surface of the filters to prevent ice build-up. ➢ Operating temperatures of the OP16 enclosure with standard air inlet system are between -20°C and +40°C.	X		
	Arctic package	Enclosure upgrade for nordic type installations with ambient temperatures between -60°C to +30°C. Including enclosure heating system, control room heating, lube oil tank and filter heating, engine compartment heating. Hydraulic pipe insulation, skid insulation, anti-icing system. Also includes ventilation air recirculation. Additional room heaters increase the parasitic power consumption to 5kW.		X	

Pos.	Component	Description	OPRA Scope: Included	OPRA Scope: Optional	OPRA Scope: Excluded
	Air inlet/outlet ducting outside the OP16 enclosure	The OP16 air inlet system is equipped with standard air openings in the OP16 air treatment and ventilation module. Additional ducting and supports (1) from outside of the building to the OP16 air inlet opening and (2) from the ventilation outlet opening to outside of the building are excluded and shall be supplied by CUSTOMER.			X
60	**<u>Control system</u>**				
	Allen Bradley based control system (Siemens S7 based control system can be provided upon request)	The OP16 control system hardware is based on Allen Bradley L71S and I/O cards belonging to the Flex I/O family. ➢ The OP16 controller (PLC) integrates turbine and other equipment controls with sub-controls and safety logic. Main controller takes care of startup and shutdown sequences, speed governing, synchronization, electrical load control, engine protection, alarm and status indication. Control system interfaces CUSTOMER control system with an industrial Ethernet/Modbus protocol. ➢ Vibration monitoring system: Bently Nevada 1900/65A vibration analyzer and Wilcoxon iT122M vibration monitor. All vibration data is processed by the control system and trends/history is displayed on the HMI. ➢ DEIF generator protection system. Generator protection and differential current protection. Modules: DEIF GPC-3 and DEIF RMC-131D. Additional Check-synch relay to safeguard synchronization. ➢ Visualization of the OP16 system is on a full-color HMI Wonderware InTouch machine edition panel. ➢ Remote monitoring and data logging system, which allows OPRA to directly monitor the performance for the genset in OPRA's headquarter (Hengelo). Requires internet connection. The high-speed internet connection is not OPRA's scope of supply.	X		
	Additional User Interface	Additional computer with identical HMI software to the HMI in the control cabinet.		X	
	Off-skid control panels	Panels are to be installed near the OP16 gas turbine package. Cabling between OP16 and control panels are included in OPRA scope, supports and trays are in CUSTOMER scope. Control cabinet dimensions are 2400mm X 2000mm X 400mm.	X		
	Air-conditioning	A 1.5kW control panel air conditioning unit with built-in thermostat is activated when the control panel temperature exceeds 35°C.	X		

Pos.	Component	Description	OPRA Scope Included	OPRA Scope Optional	OPRA Scope Excluded
70	**Transport, installation & commissioning**				
	Due to the modular and standardized design of the OP16 genset, the time required for the installation and commissioning can be reduced to a minimum. A total of 20 man days are included in the scope of this contract for Installation and commissioning of one OP16 Gen set. The installation and commissioning is divided into three distinct phases (see Phase 1, 2 and 3 as detailed below). Installation & commissioning schedule and scope are further defined in Appendix F and Appendix G. Prior to the start of the respective phases, Customer shall declare that all preparations for the next phase have been completed in accordance with their respective specification as provided by OPRA. This declaration shall be carried out by completing and signing the checklist in Appendix G, "Pre Installation and Commissioning Sign Off List"				
	Delivery terms	FCA Hengelo, The Netherlands according to Incoterms 2010	X		
	Civil works	All civil works required to install and operate the OP16 gas turbine generating set. Foundation requirements as per Appendix D.			X
	Lifting and positioning	Lifting with a suitable crane or other equipment from the truck onto the final position of the OP16 turbine at CUSTOMER site.			X
	Unloading	Unloading of equipment from the truck at site and positioning the equipment on its final place according OPRA Turbines specifications.			X
	I&C Phase 1, supervision of placement	Supervision of Genset placement on foundation and setting interface between genset enclosure and Air Treatment Module, details in Appendix F.	X		
	I&C Phase 2, installation and connection of system interfaces	Installation and connection of ducting, gas pipes, cables, exhaust and other interfaces to the battery limits.			X
	I&C Phase 3, Commissioning	Commissioning and handover of the Equipment, as detailed in Appendix F.	X		

Pos.	Component	Description	Included	Optional	Excluded
80	**Engineering and training services**				
	Training	Operator and maintenance training of CUSTOMER employees for safe operation of the OP16 gas turbine generating set (2 full days for a total of 1 shift).		X	

Pos.	Component	Description	Included	Optional	Excluded
90	**Certifications, tests and approvals**				
	OP16 core engine factory acceptance test	An OPRA standard core OP16 engine performance, signal, vibrations and duration test. Test performed in the engine test facilities in Hengelo.	X		
	OP16 system functionality test	OP16 gas turbine system full functionality test in Hengelo. Test aimed to check equipment is correctly installed and working, assessing system safety, start and shutdown procedures.	X		
	OP16 system full load test	Full functional OP16 gas turbine system full load test in Hengelo. Test aimed to check equipment is correctly installed and working, assessing system safety, start and shutdown procedures and full load performance.		X	

Pos.	Component	Description	Included	Optional	Excluded
100	**Documentation**				
	User and operation manual	English language document includes equipment and interface drawings.	X		
	P&IDs	English language, P&ID drawings.	X		
	Manufacturer Record Book	English language, includes test reports, quality certificates and special components lists.	X		

Pos.	Component	Description	OPRA Scope		
			Included	Optional	Excluded
	Maintenance manual	English language, includes how to maintain the OP16 system.	X		
	Tagging system	All components numbers are shown on the equipment and in the documentation. Simple tagging on equipment and documentation. Numbering according to OPRA specification. Units on transmitters etc. and in Imperial units.		X	

3.2 Interfaces to scope of supply

3.2.1. Controls Interfaces

- **Control system connection**: The OP16 control system interfaces with a port connection to integrate selected parameters into CUSTOMER site control system. Cabling between OP16 system and CUSTOMER control system excluded.
- **Load limitation**: A 4-20 mA (0 – 100 % of max power) signal can be used to control the energy output of the generator. The OP16 set-point is adjusted following a 4-20mA signal.
- **Internet connection**: Cable-speed internet connection is required for remote monitoring of the OP16 gas turbine generating set. Interfacing the OP16, the internet connection and cabling are excluded from OPRA scope.
- **Switchgear and transformer controls**: OP16 control system has open ports to connect to the switchgear and transformer to control starts/stops. Equipment is to be designed according to OPRA requirements. All cables, switchgear and transformer are excluded from OPRA scope.
- **Gas fuel flow meter**: Certified gas fuel meter for determine OP16 efficiency. The OP16 receives a pulse signal (open collector, suitable for 24 Vdc, non ATEX) reflecting 1000 pulses / Nm^3. Alternatively a 4-20mA current feedback signal can be used. Gas fuel flow meter is not included in OPRA Scope.

3.2.2. Fuel Interfaces

- **Gas connection**: Connection of the CUSTOMER gas system to the OP16 gas system found at the OP16 enclosure edge. Interface will be a flanged DN50/PN16 OR welded pipe DN50 connection.
- **Gas ventilation pipe interface**: interfacing at OP16 enclosure edge. Can be an Ermote fitting or welded pipe DN15/PN16 connection.

3.2.3. Mechanical Interfaces

- **Pressurized air interface**: Continuous 6-8 barg pressurized air connection for fuel valve operation. Maximum air consumption $0.1Nm^3/h$, interface connection female ¼ BSPP located at skid edge.
- **Air intake**: a combined air intake is found at the generator side of the air filtration and ventilation module. When applicable, inlet air ducting can directly connect to the air filtration module.
- **Exhaust system interface**: Metal expansion joint (AISI 321) with a flange connection located at skid edge. Maximum allowable force 1000N in axis direction and 500N in a vertical or horizontal direction. Engineering parameters with respect to the bellow and transitioning piece are provided in Appendix C.
- **OP16 foundation**: The OPRA skid requires multiple support points. Proper foundation shall be provided by CUSTOMER, for which OPRA provides the engineering parameters in Appendix D.

3.2.4. Electrical Interfaces

- **Generator cable connection**: OP16 genset is delivered with terminal box allowing easy connection for power cables. All cabling, hookup and supports inside the enclosure are excluded.
- **Auxiliary power**: Following the power requirement detailed in the Utility List in Appendix A, End-user / contractor shall provide cabling up to the OP16 MCC supplying 400V/480V 3 phase, N, PE, 160-250A 50/60 Hz power. The firefighting system requires a separate power supply to be provided by CUSTOMER.
- **Earthing of the OP16 Package**: The control system requires clean earthing (M12 bolt, $25mm^2$ cable) and protective earthing (M12 bolt, minimum $25mm^2$ cable). Turbine enclosure protective earthing interfacing at enclosure edge via copper strip (30mm x 5 mm, 925mm length, $95mm^2$). Earth wiring and strips are CUSTOMER supplied.
- **Generator Star Point Connection**: Generator comes with for a floating start point. Provisions for earthed start point are available and can be quoted as an option.
- **Neutral bus connection point**: Connection point for a resistor coil to connect the generator and earth is standard not included, but can be quoted as an option.

3.3 Preliminary generator set package drawings

The drawings sent with this proposal are general preliminary drawings, provided for illustrative purposes only and are not to be used for installation purposes.

Detailed engineering is to be done at a later stage. Upon receipt and acceptance of an order for a generator package, OPRA will prepare a complete set of detailed installation drawings and CUSTOMER interface connections.

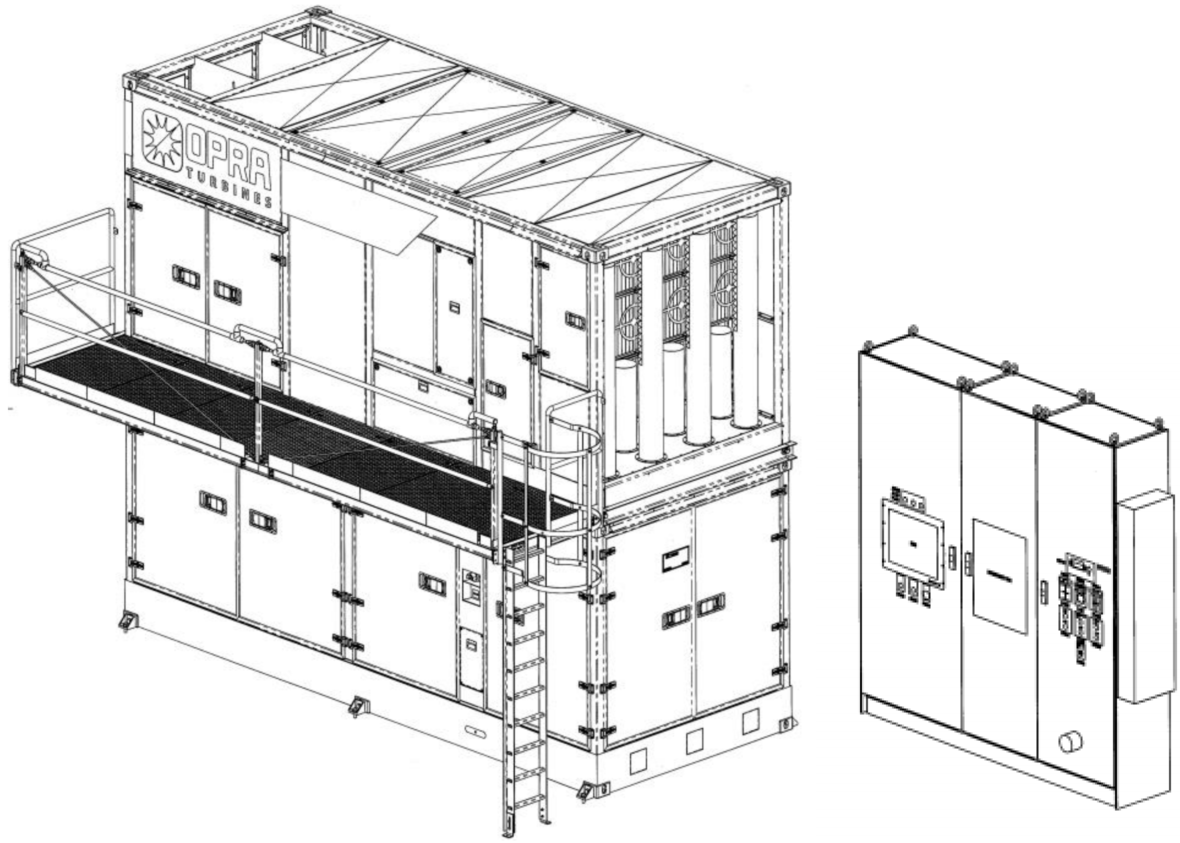


Figure 4: Example package configuration
(a) Separate Control Cabinets

4. Maintenance

The OP16 gas turbine generating set, its enclosure and supporting systems are designed keeping simplicity and robustness in mind. This provides the OP16 system with unique properties in the area of maintenance: properties widely appreciated in the industry.

4.1.1 Compact engine

The small size of the engine enables quick removal of the OP16 engine during the major overhaul period, translating into short standstill times. A major overhaul of the OP16 system can be performed in 7 working days. The easily removable combustor cans allow for quick borescope of the hot flow path section.

4.1.2 Maintenance free lube oil system

- *No lubrication oil consumption*
  In contrast with any other machine the OP16 consumes virtually zero oil. The cold-end bearings give the lubrication oil a relative low temperature which prevents the oil from evaporating and causing problems in the bearings. The oil has a minimum lifetime of 42.500 hours and only needs to be replaced when it has lost its properties.

- *Integrated oil system*
  The duplex lube oil filter is mounted inside a compartment integrated in the enclosure wall, so oil filters can be changed without the need to stop the turbine. The complete lubrication oil system (including the air cooled oil cooler) is integrated inside the OP16 enclosure. The OP16 turbine heavy structural base is able to contain the 200 liters of oil stored in the oil tank. In case of an unexpected leakage, no lubrication oil can spill into the environment.

4.1.3 Flexible maintenance space requirements

- *Compact maintenance areas*
  The maintenance areas depicted in the attached General Arrangement drawing enable easy opening of doors, thus allowing for engine or generator removal. As a general rule there should be a reserved area next to each package of approximately 2500 mm (8.2 ft). Maintenance area can be optionally on the right or left side of the unit only.

- *Single side maintenance access*
  As the OP16 turbine enclosure and air treatment module have been designed and constructed in such a way to provide optimum access and maintainability, full maintenance can be performed on the turbine package and air ventilation and treatment module from both sides.

4.1.4 Air inlet filters

- *Optimum design*
  The proposal includes ventilation and engine intake filters of the standard type. The filters may need regular replacement depending on operation philosophy and environmental conditions. All systems in the package have been designed and constructed in such a way to provide optimum access and maintainability.

- *Two filter stages*
  The radial design of the OP16 turbine makes cooling of the turbine wheel unnecessary. Due to the absence of cooling holes in the OP16 rotor, which can get clogged when the turbine combustion air is not filtered properly, the OP16 turbine requires less filtering and combustion air goes through only two filter stages (G4 and F9). This translates into a lower inlet pressure drop and a lower maintenance requirements and expenses compared to other turbines.

- The filters can be changed during operation of the OP16 gas turbine and requires no downtime.

4.1.5 Remote monitoring
A direct internet connection to OPRA Turbines headquarters allows the in-house maintenance team to monitor all controls parameters remotely.

4.1.6 Long term service schedule
The simple and robust design of the OP16 gas turbine generating set provides a very friendly maintenance schedule:

- One yearly preventive maintenance inspection;
- A major overhaul after 42.500 fired hours. The engine is taken out of the package and shipped back to Hengelo, The Netherlands. In the meantime the engine is replaced by an engine from the exchange pool, or with a new engine. Total number of standstill days for swapping engines is 7 working days;

LTSA proposals
The in-house OPRA service department can provide standard or tailor made LTSA proposals on request.

5. Project management

A stress free project management phase is ensured due to standardization of the OP16 system.

Because of this standardization of the OP16 system, custom-engineered solutions are reduced to a minimum and interfaces are known before the project even starts. This reduces stress and headaches in the process until finishing turnkey installation.

OPRA's Project Management team provides clear documentation regarding the physical and controls interfaces and required plans at the right time to ensure a seamless integration of the OP16 in CUSTOMER system.

The following standardized information is provided to the system integrator:

- Documentation following OPRA Turbines SMDR;
- Documented engineering parameters specifying interfaces and requirements to equipment external to OPRA scope of supply;
- Document and engineering support related to governmental approval of OP16 system;
- Document support for civil works, interfaces, electrical and controls related to OP16 system integration;

Additionally the OPRA Turbines Project Manager(s) attend or will organize the following meetings:

- First project kickoff meeting;
- One safety philosophy and risk assessment meeting.

These meetings can be held either at CUSTOMER location or OPRA can host the meetings in OPRA Turbines headquarters in Hengelo.

OPRA Turbines is able to provide additional engineering support and/or limited project management for equipment outside OPRA scope of supply at a separate project management fee.

6. OP16 Site Performance

The site performance data provided below is provided for illustrative and planning purposes only. The performance data is based on operation of one generator package at the following site conditions:

Site Conditions		
Ambient Temperature Range	**[degF]**	-20 to +90
Elevation	**[ft]**	3200
Relative Humidity	[%]	60
Absolute Inlet Loss	**[in. WC]**	4
Absolute Exhaust Loss	**[in. WC]**	10

Engine Configuration		
Engine Type		3B

Fuel type		
Fuel		NG
Fuel lower heating value	**[MJ/kg]**	46
Fuel density	**[kg/Nm3]**	0.767
Dew point temperature	**[°C]**	-15

Generator Configuration		
Gen Type		13.8kV
Power Factor		1.0

The below table shows the maximum rated site performance based on the above assumptions.

Air intake temperature	Electrical Power	Electrical Efficiency	Exhaust gas temp.	Fuel Flow	Exhaust Flow
[degF]	[kW]	[%]	[degF]	[MMBtu/h]	[lbs/h]
-20	2104	26.4%	1015	27.2	72897
-10	2030	26.0%	1023	26.6	71925
0	1955	25.5%	1031	26.1	70982
10	1876	25.0%	1038	25.5	70009
20	1787	24.6%	1045	24.8	68344
30	1704	24.1%	1052	24.0	66725
40	1627	23.7%	1059	23.4	65208
50	1557	23.3%	1066	22.8	63765
60	1490	22.8%	1073	22.2	62343
70	1395	22.1%	1081	21.5	60641
80	1309	21.4%	1090	20.9	59015
90	1234	20.7%	1101	20.3	57449

7. List of Appendices

- Appendix A – OP16 Utility List
- Appendix B - OP16 Typical General Arrangement - Separate control cabinet
- Appendix C - OP16 exhaust interface
- Appendix D - OP16 Foundation Requirements
- Appendix E - Typical Installation and Commissioning plan
- Appendix F - IC schedule and scope
- Appendix G – Pre-Installation and Commissioning Sign Off List

Solar Turbines Incorporated
Budgetary Estimate for U of Montana

Inquiry #
September 16, 2016
For more information contact Lisa Marlo Conley, 858 694-6523, lisamarloconley@solarturbines.com
(Prices shown below quoted in US Dollars $)

Quotation is for information only and does not constitute Solar's agreement to offer a firm proposal in the future.

Gas Turbine Equipment

(1) Centaur 50 SoLoNOx Turbine Generator Set, Natural Gas……………………………………$3,117,500
Commissioning Parts, Startup, and Site Testing……………………………………$179,000

Electrical Equipment

No Additional Electrical Equipment Included

Mechanical Equipment

1 Heat Recovery Steam Generator with ductburners……………………………………$1,245,000
Total for Heat Recovery Steam System……………………………………$1,244,900

Miscellaneous

Construction Estimate……………………………………by others
Project Management & Engineering (Loose Ship Equipment Only)……………………………………$87,100
Shipping……………………………………$90,800
0% Balance of Plant Contingency……………………………………$

Total for BOP Equipment (installation not included)……………………………………$1,422,800
Grand Total for Turbomachinery and Balance of Plant……………………………………$4,719,300
Estimation of cost per ISO rating kilowatt for selected equipment……………………………………$1,025
FSA Cost per Month (Only Turbomachinery Covered)……………………………………$31,640

*Duties and taxes not included in estimate.

 CEP Version 10.1

Centaur 50-T6200S Generator Set Package Features

Gas Turbine:

One shaft turbine, designed for industrial use
Axial compressor design
Annular type combustor employing dry, low NOx technology (15 ppm NOx @15%O2)

Basic Options:

Fully enclosed, generator set package requiring 460V, 3-phase, 60 Hz AC power
Rated Class I, Div II, Groups C,D per NEC
120V, 1-phase, 50/60 Hz internal lighting and heater power
Gas turbine engine in upward oriented air inlet and axially oriented exhaust outlet
1800 rpm; 60 Hz
Continuous Duty, Open Drip Proof Medium voltage generator featuring Class F insulation, B rise

Included Package Features:

Direct AC start motor system
Duplex lube oil filter system
Allen-Bradley based Turbotronics control system including:
- Ethernet network interface
- Touch Screen display with Engine Performance map
- Software for heat recovery interface (without diverter valve control)
- Software for CO2 system "lock out" (maintenance access to enclosure)
- Backup Safety Shutdown System
- kW Control
- kVAR/Power Factor Control

Included Factory Testing/Customer Witness/Quality Control Documentation:

Standard package dynamic testing
Factory vibration testing
Factory emissions testing per Solar's ES 9-97
Observation on "Non-Interference" basis
Quality Control documentation (Level 1)

Field-installed Ancillary Equipment (excludes ducting):

Updraft, three-stage Camil-Farr air inlet filter
Engine air inlet silencer
Exhaust bellows (interface to waste heat recovery equipment)
Elbow type enclosure inlet/exhaust ventilation system with silencer

Included "Off-Skid" Components/Systems:

Remote desktop PC/monitor and Printer/Logger
Gas fuel flow meter (for Gas-only and Dual Fuel configurations)
AC motor-driven Liquid Fuel boost pump skid (for Liquid Fuel configurations)
3-micron duplex filter/coalescer with auto drain (for Liquid Fuel configurations)
CO2 system cabinet
Air/Oil lube oil cooler
VRLA Batteries with 120V DC charging system (back-up post lube)
Portable engine cleaning cart

Miscellaneous

Short-term preservation for shipment
Four (4) paper copies of Solar's Instruction, Operation and Maintenance manuals
Four (4) CD-ROM copies of Solar's Instruction, Operation and Maintenance manuals
UV Light and Gas Sensor test kit
Internal equipment handling system

Cogeneration Plant Estimated Performance Summary

U of Montana

Solar Turbines Incorporated

September 16, 2016

Performance listed below is estimated, not guaranteed.

Gas Turbine:		
KW Gross Output @ ISO Conditions:	4,600	kW
Site Ambient Temperature for Performance Analysis:	59	°F
Site Elevation for Performance Analysis:	3,209	feet
Site Ambient Relative Humidity for Performance Analysis:	60	%
Turbine Inlet Pressure Loss:	4.0	"H2O
Turbine Outlet Pressure Loss:	10.0	"H2O
Turbine Fuel Consumption @ specified site conditions (LHV):	47.0	MMBtu/hr
KW Gross Output @ specified site conditions:	3,900	kW
Turbine Auxiliary Power:	10	kW
Condensate Pump Power:	1.4	kW
Boiler Feed Pump Power:	15.2	kW
Total Auxiliary Power Consumption:	27	kW
Net Gas Turbine Power Production:	3,874	kW
Black Start kW Requirement (Turbine Generator Set Only):	200	kW

Boiler:		
Condensate Return:	60	%
Condensate Temperature:	212	°F
Makeup Water Temperature:	70	°F
Process Steam Pressure:	175.0	psig
Process Steam Temperature:	377	°F
Steam Contributed by Gas Turbine:	22,307	lbm/hr
Steam Contributed by Ductburners:	20,665	lbm/hr
Ductburner Fuel Consumption (LHV):	18.2	MMBtu/hr
Deaerator Steam Consumption:	2,972	lbm/hr
Boiler Steam Flow (HRSG design uses 27°F pinch, 18.0°F approach):	42,972	lbm/hr
Steam Flow to Process:	40,000	lbm/hr

Cycle Performance (lower heating value basis):		
Net Turbine Electrical Heat Rate:	12,120	Btu/kWHR
Gross Plant Heat Rate (Process steam or Tons converted to equivalent KW):	3,950	Btu/kWHR
Overall Cycle Efficiency (LHV):	86.3	%

CEP Version 10.1

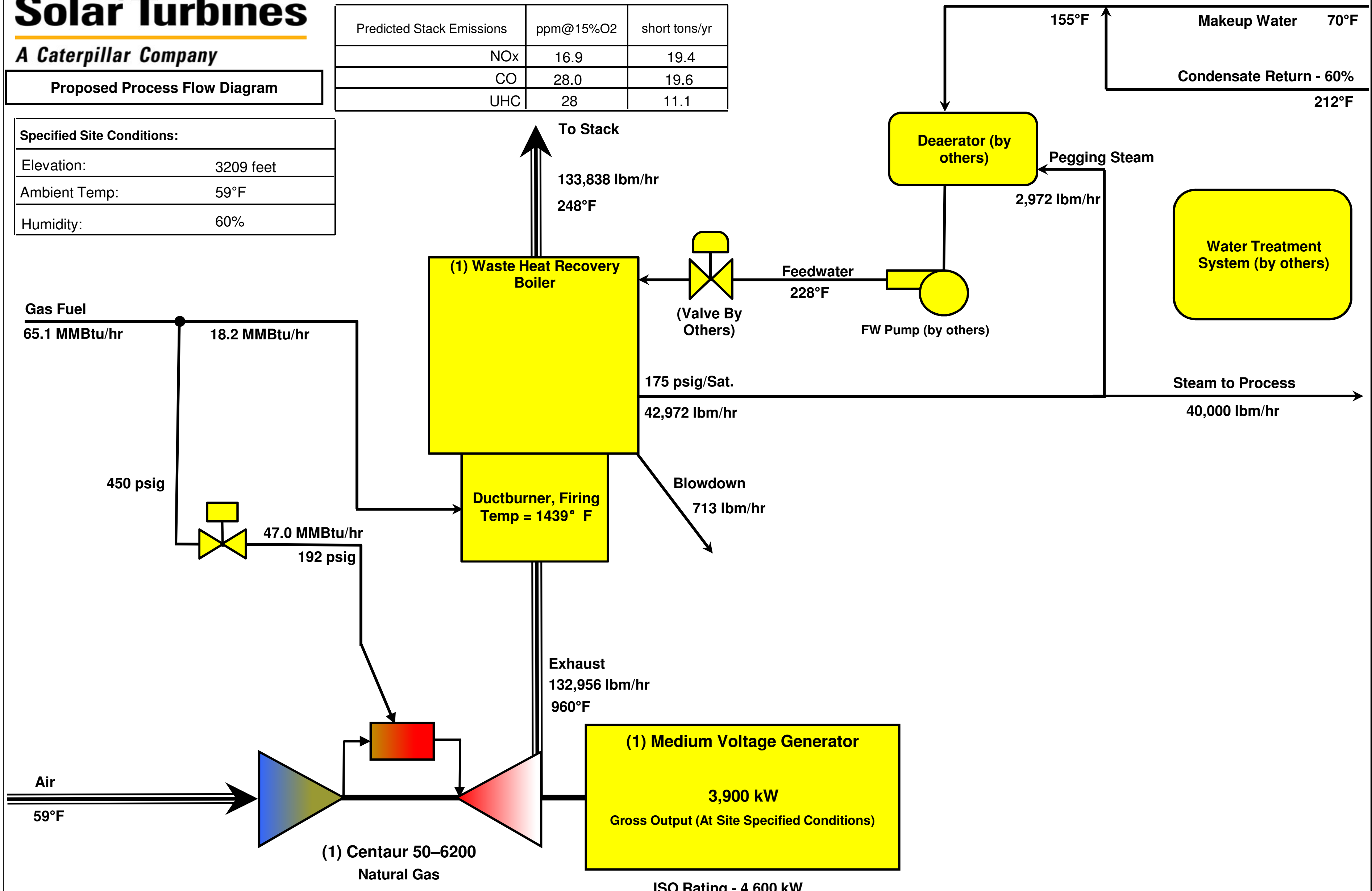
Solar Turbines

A Caterpillar Company

Proposed Process Flow Diagram

Predicted Stack Emissions	ppm@15%O2	short tons/yr
NOx	16.9	19.4
CO	28.0	19.6
UHC	28	11.1

Specified Site Conditions:	
Elevation:	3209 feet
Ambient Temp:	59°F
Humidity:	60%



CEP Version 10.1

System Efficiency = 86.3%

Fuel Flow(s) based on Lower Heating Value

Note: For Estimating Purposes only. For Guaranteed Performance, see your Solar Turbines Representative.

U of Montana		
Ref. #	1/0/1900	September 16, 2016
Designed by	Lisa Marlo Conley	

Off Design Performance Worksheet

U of Montana

September 16, 2016

Prepared by Lisa Marlo Conley

Centaur 50-T6200S

Natural Gas

Process Steam Demand	40,000	lbm/hr
Unfired Steam Flow	20,828	lbm/hr
Max Steam Flow	40,248	lbm/hr
Firing Temperature	1,429	°F
Duct Burner Fuel Flow	18.1	MMBtu/hr

	As-Designed Values	
Site Elevation	3,209	feet
Barometric Pressure	26.57	"Hg
Inlet Duct Loss	4.0	"H2O
Exhaust Duct Loss	10.0	"H2O

	As-Designed Values						
# of Turbines in Service	1	1	1	1	1	1	
Ambient Temperature (T1)	59.0	23.0	34.0	44.0	72.0	54.0	°F
Relative Humidity	60.0	60.0	60.0	60.0	60.0	60.0	%
Part Power (kW), % Load, or 0 for Max	0	0.0	0.0	0.0	0.0	0.0	kW
Engine Inlet Air Temperature (T1)	59.0	23.0	34.0	44.0	72.0	54.0	°F
Nominal Output Power @ Terminals	3,900	4,347	4,216	4,100	3,701	3,964	kW
Fuel Flow (LHV)	47.0	51.3	50.0	48.9	45.2	47.6	MMBtu/hr
Inlet Air Flow	130,677	139,697	137,332	135,013	126,499	132,092	lbm/hr
Exhaust Gas Temperature (T7)	960	943	943	947	968	956	°F
Exhaust Gas Mass Flow	132,956	142,187	139,760	137,384	128,692	134,400	lbm/hr
Exhaust Gas Volumetric Flow	33,856	36,228	35,601	34,990	32,764	34,203	SCFM
Nominal Electrical Efficiency @ Terminals	28.3	28.9	28.8	28.6	27.9	28.4	%
Nominal Electrical Heat Rate @ Terminals	12,042	11,800	11,865	11,917	12,214	12,002	Btu/kWHR
Exhaust Heat Captured	24.6	25.7	25.2	24.9	24.1	24.7	MMBtu/hr
% Argon, wet	0.9	0.9	0.9	0.9	0.9	0.9	
% CO2, wet	3.0	3.1	3.0	3.0	3.0	3.0	
% H2O, wet	6.4	6.5	6.5	6.5	6.4	6.3	
% N2, wet	75.3	75.3	75.3	75.3	75.3	75.4	
% Oxygen, wet	14.4	14.2	14.3	14.3	14.4	14.4	
					Net CHP System Efficiency =	85.9	%

Fuel Flow(s) based on Lower Heating Value

Solar Turbines Incorporated

Budgetary Estimate for

Inquiry # prepared on February 2, 2016

For more information contact:

Lisa Marlo Conley, 858 694-6523, lisamarloconley@solarturbines.com

(Prices shown below quoted in US Dollars $)

Quotation is for information only and does not constitute Solar's agreement to offer a firm proposal in the future.

Gas Turbine Equipment		
(1) Natural Gas Fuel, Mercury 50 SoLoNOx Turbine Generator Set................................		$4,500,000
Commissioning Parts, Startup, and Site Testing..		$191,500
Electrical Equipment		
No Additional Electrical Equipment Included		
Mechanical Equipment		
1 Heat Recovery Steam Generator with ductburners.......	$1,524,000	
HRSG Options...	none selected	
Total for Heat Recovery Steam System..		$1,524,000
Miscellaneous		
Construction Estimate...		by others
Project Management & Engineering (Loose Ship Equipment Only)................		$106,600
Shipping..		$93,300
0% Balance of Plant Contingency...		$0
Total for BOP Equipment (installation not included)....................................		$1,723,400
Grand Total for Turbomachinery and Balance of Plant.........................		**$6,414,900**
Estimation of cost per ISO rating kilowatt for selected equipment..................		$1,394
FSA Cost per Month (Only Turbomachinery Covered)................................		$60,360

*Duties and taxes not included in estimate.

CEP Ver. 9.2

MERCURY 50-6400R Generator Set Package Features

Gas Turbine:

Single shaft turbine, designed for industrial use
Axial compressor design
Annular type combustor employing dry, low NOx technology

Basic Options:

Fully enclosed, generator set package requiring 460V, 3-phase, 60 Hz AC power
Rated Class I, Div II, Groups C,D per NEC
120V, 1-phase, 60 Hz internal lighting and heater power
Gas turbine engine in upward oriented air inlet, and upward oriented exhaust outlet
1800 rpm, 60 Hz
Continuous Duty, Open Drip Proof Medium voltage generator featuring Class F insulation, B rise

Included Package Features:

Direct AC start motor system
Duplex lube oil filter system
Allen-Bradley based Turbotronics IV control system including:

- Ethernet network interface
- Touch Screen display with Engine Performance map
- Software for heat recovery interface (without diverter valve control)
- Software for CO2 system "lock out" (maintenance access to enclosure)
- Backup Safety Shutdown System
- kW Control
- kVAR/Power Factor Control

Included Factory Testing/Customer Witness/Quality Control Documentation:

Standard package dynamic testing
Factory vibration testing
Factory emissions testing per Solar's ES 9-97
Observation on "Non-Interference" basis
Quality Control documentation (Level 1)

Field-installed Ancillary Equipment (excludes ducting):

Medium velocity, three-stage Camil-Farr air inlet filter
Engine air inlet silencer
Exhaust bellows (interface to waste heat recovery equipment)
"Elbow" type enclosure inlet/exhaust ventilation system with silencer

Included "Off-Skid" Components/Systems:

Remote desktop PC/monitor and Printer/Logger
Gas fuel flow meter (for Gas-only and Dual Fuel configurations)
AC motor-driven Liquid Fuel boost pump skid (for Liquid Fuel configurations)
3-micron duplex filter/coalescer with auto drain (for Liquid Fuel configurations)
CO_2 system cabinet
Air/Oil lube oil cooler
VRLA Batteries with 120V DC charging system (back-up post lube)
Portable engine cleaning cart

Miscellaneous

Short-term preservation for shipment
Four (4) paper copies of Solar's Instruction, Operation and Maintenance manuals
Four (4) CD-ROM copies of Solar's Instruction, Operation and Maintenance manuals
UV Light and Gas Sensor test kit
Internal equipment handling system
Recuperator removal tool

Cogeneration Plant Estimated Performance Summary

0

Solar Turbines Incorporated

February 2, 2016

Performance listed below is estimated, not guaranteed.

Gas Turbine:		
KW Gross Output @ ISO Conditions:	4,600	kW
Site Ambient Temperature for Performance Analysis:	59	°F
Site Elevation for Performance Analysis:	3,209	feet
Site Ambient Relative Humidity for Performance Analysis:	60	%
Turbine Inlet Pressure Loss:	4.0	"H2O
Turbine Outlet Pressure Loss:	7.0	"H2O
Turbine Fuel Consumption @ specified site conditions (LHV):	35.8	MMBtu/hr
KW Gross Output @ specified site conditions:	3,941	kW
Condensate Pump Power:	1.4	kW
Boiler Feed Pump Power:	17.9	kW
Total Auxiliary Power Consumption:	59	kW
Net Gas Turbine Power Production:	3,882	kW
Black Start kW Requirement (Turbine Generator Set Only)	206	kW

Boiler:		
Condensate Return:	60	%
Condensate Temperature:	212	°F
Makeup Water Temperature:	70	°F
Process Steam Pressure:	175.0	psig
Process Steam Temperature:	377	°F
Steam Contributed by Gas Turbine:	10,163	lbm/hr
Steam Contributed by Ductburners:	32,049	lbm/hr
Ductburner Fuel Consumption (LHV):	28.8	MMBtu/hr
Deaerator Steam Consumption:	2,965	lbm/hr
Boiler Steam Flow:	42,212	lbm/hr
Steam Flow to Process:	39,247	lbm/hr

Cycle Performance (lower heating value basis)**:**		
Net Turbine Electrical Heat Rate:	9,220	Btu/kWHR
Gross Plant Heat Rate (Process steam or Tons converted to equivalent KW):	3,920	Btu/kWHR
Overall Cycle Efficiency (LHV):	87.1	%

Caterpillar: Confidential Green

CEP Ver. 9.2

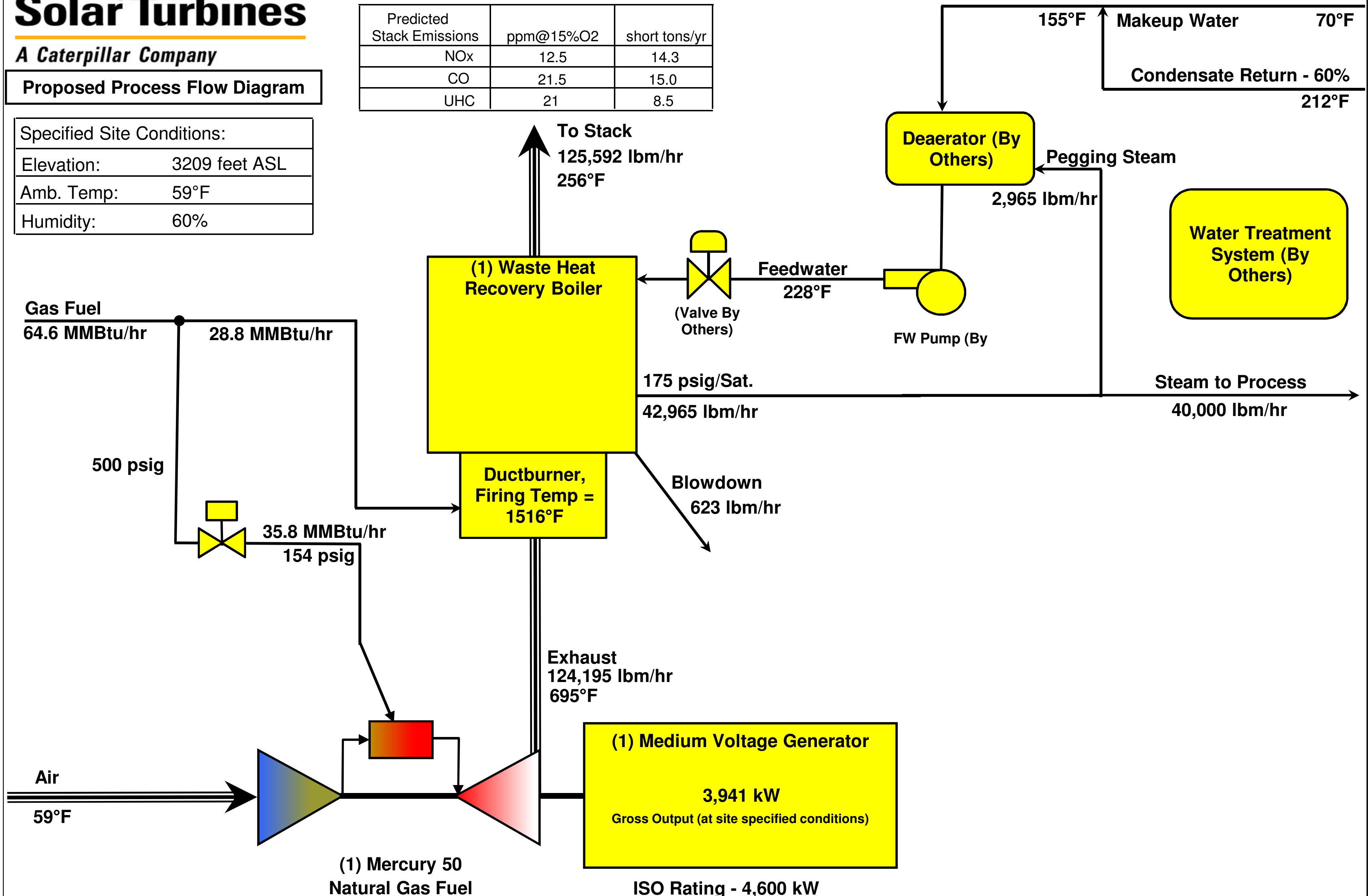
Solar Turbines

A Caterpillar Company

Proposed Process Flow Diagram

Predicted Stack Emissions	ppm@15%O2	short tons/yr
NOx	12.5	14.3
CO	21.5	15.0
UHC	21	8.5

Specified Site Conditions:	
Elevation:	3209 feet ASL
Amb. Temp:	59°F
Humidity:	60%



CEP Ver. 9.2

System Efficiency = 87.1%

Fuel Flow(s) based on Lower Heating Value

Note: For Estimating Purposes only. For Guaranteed Performance, see your Solar Turbines Representative.

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Ref. #	1/0/1900	2/2/2016
Designed by	Lisa Marlo Conley	

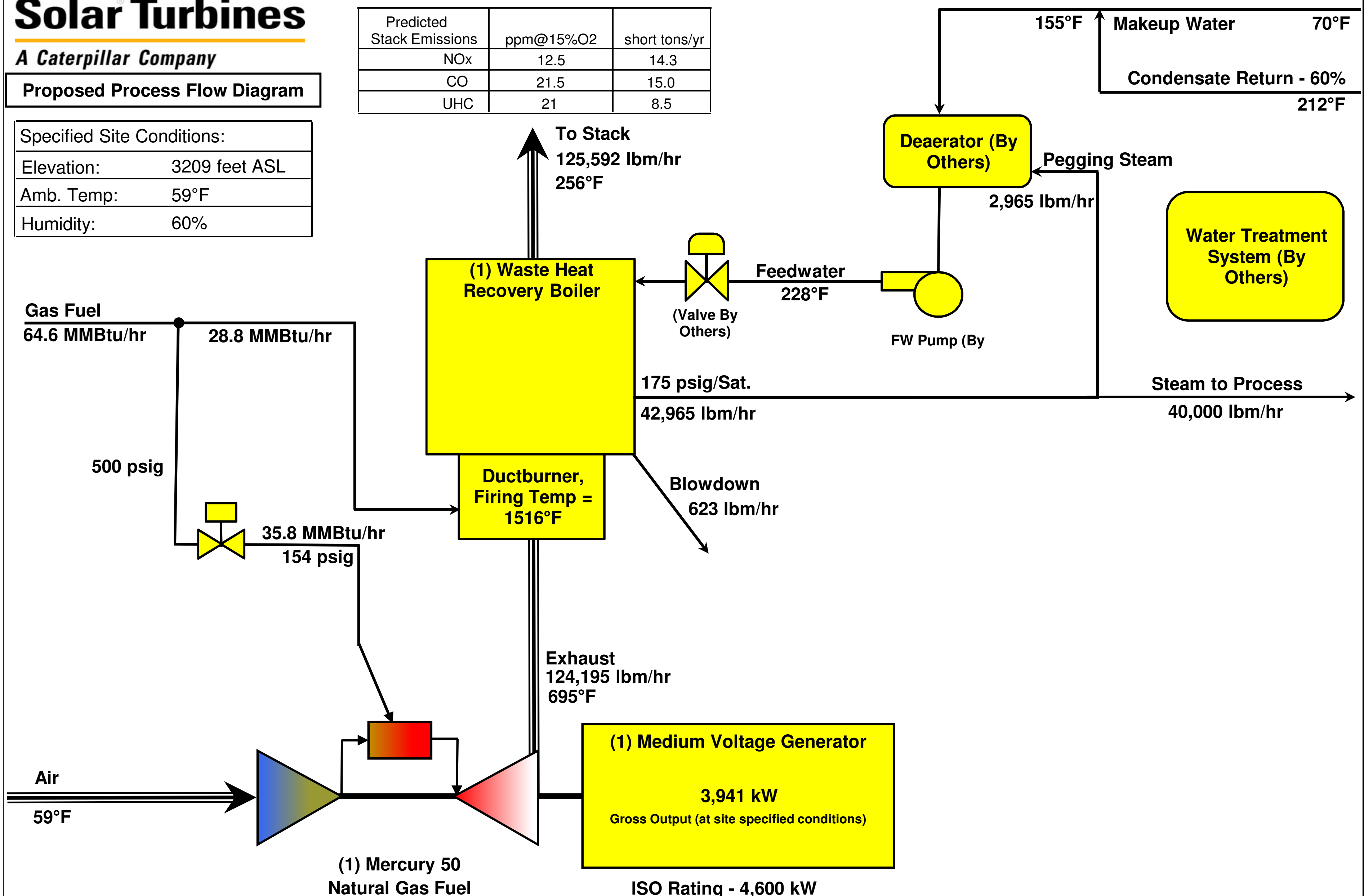
Solar Turbines

A Caterpillar Company

Proposed Process Flow Diagram

Predicted Stack Emissions	ppm@15%O2	short tons/yr
NOx	12.5	14.3
CO	21.5	15.0
UHC	21	8.5

Specified Site Conditions:	
Elevation:	3209 feet ASL
Amb. Temp:	59°F
Humidity:	60%



CEP Ver. 9.2

System Efficiency = 87.1%

Fuel Flow(s) based on Lower Heating Value

Note: For Estimating Purposes only. For Guaranteed Performance, see your Solar Turbines Representative.

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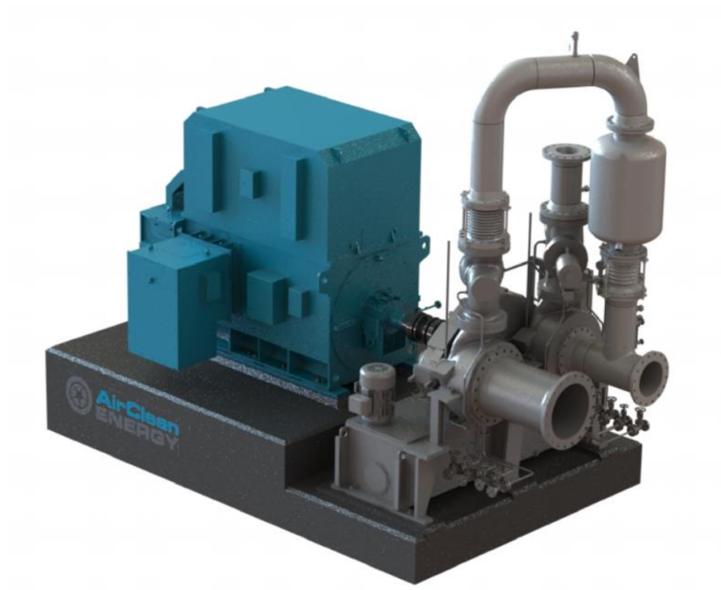
Ref. #	1/0/1900	2/2/2016
Designed by	Lisa Marlo Conley	

Appendix D - Dual Pressure Steam Turbine Generator

AirClean ENERGY

AirClean Project:
ACQ-16096-UMO R1



High Efficiency Synchronous
Dual Pressure Steam Turbine Generator
University of Montana

October 24, 2016

Presented to:	CTA Architects 316 North Last Chance Gulch Helena, MT 59601 Attn: Rick DeMarinis

AirClean Energy
4725 W Marginal Way SW
Seattle, WA 98106
206-860-4930
www.aircleanenergy.com

Your AirClean Representative:
Dave Salem
Brad Thompson Co
Phone: (206) 619-3920
daves@bradtco.com

October 24, 2016

CTA Architects
316 North Last Chance Gulch
Helena, MT 59601

Attention: Rick DeMarinis

Subject: University of Montana
High Efficiency Synchronous Dual Pressure Steam Turbine Generator

Dear Mr. DeMarinis,

I am pleased to offer this proposal for your review. We have provided a synchronous dual pressure turbine generator system based on the conditions provided for the University of Montana. The following proposal outlines the scope of this system.

If you have any questions or require additional information, please don't hesitate to contact me. On behalf of AirClean Energy, we look forward to working with you.

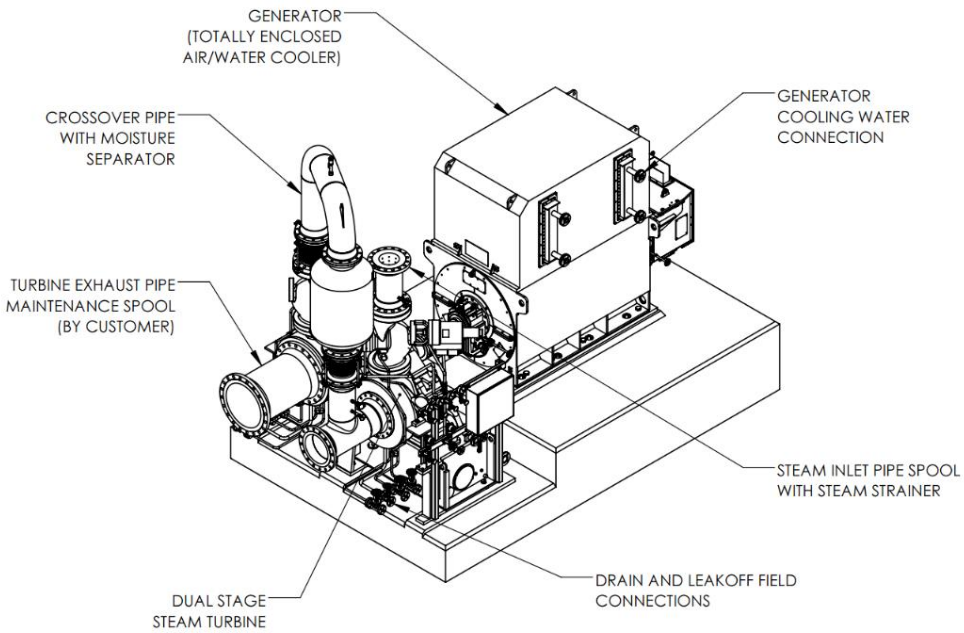
Best regards,

Bill Hunter, P.E.

AirClean Energy
bhunter@aircleanenergy.com
www.aircleanenergy.com

Your AirClean Representative:
Dave Salem
Brad Thompson Co
Phone: (206) 619-3920
daves@bradtco.com

STEAM TURBINE GENERATOR DESIGN:



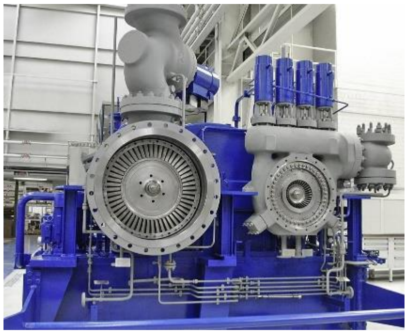
Steam Conditions – High Case				
Mass Flow (lb/hr)	**Location**	**Pressure (psig)**	**Temperature (°F)**	**Power (kWe)**
30,000	**Inlet**	175	Sat	1500
	Extraction	30	Sat	
22,000	**Condensing**	-13	115	

Synchronous Turbine Generator package utility requirements:

Cooling water: .... 91 GPM (freshwater) at maximum 86°F
Power: .... 480 VAC 3-phase

Your AirClean Representative:
Dave Salem
Brad Thompson Co
Phone: (206) 619-3920
daves@bradtco.com

MECHANICAL SYSTEM DESCRIPTION:

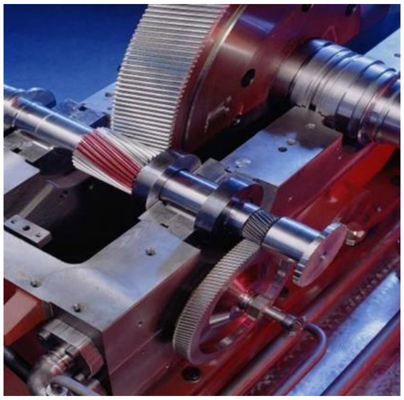


The following features are provided with this turbine design:

- Vertical split casings
- Over hung – solid disk milled turbine wheel
- Quick acting hydraulic trip and inlet control valve
- Anti-friction rotor locator thrust bearing with anti-rotation band
- Carbon ring type end gland shaft seals
- Gear wheel speed pickup mounted on the turbine shaft
- Eight (8) drain valves (auto control possible)
- Thermally insulated by mineral wool blankets
- Cyclone type inlet moisture separator, supplied loose
- Cyclone type moisture separator to be integrated into the AirClean supplied turbine crossover piping

Integral Gear Reducer

- Single helical gearing
- Six (6) forced-oil lubricated hydrodynamic sleeve bearings
- Ground gearing, combined with contact pattern adjustment during assembly, guarantees extremely low vibration levels and low noise
- Horizontally-split allows easy inspection of gears and bearings
- Turbine wheels are mounted onto the pinion shafts by a self-centering Hirth-toothed coupling
- Resistance thermometer PT 100 on each gearbox bearing insert



Circulating Oil System

- Carbon steel reservoir
- 3-minute retention time
- Hydraulic rack with pressure/temperature gauges, overflow valves etc.
- Sight glass for oil level indication
- Water Cooled oil heat exchanger
- Duplex oil filter (filter mesh 10 µm) with changeover valve and fouling indicator
- Mechanically driven main oil pump (integrated into gearbox /shaft driven /100%)
- Electrically driven auxiliary oil pump

Your AirClean Representative:
Dave Salem
Brad Thompson Co
Phone: (206) 619-3920
daves@bradtco.com

ELECTRICAL SYSTEM DESCRIPTION:

Synchronous Generator Features:

- 1,500 kW generator rating
- 4.2 kV
- 3 Phase/ 60 Hz
- 0.8 PF
- 4 Poles (1,800 RPM)
- Frame Size TBD
- Protection/Cooling – IP54/TEWAC
- Insulation Class F with Temp Rise Class B
- Enclosure: Totally Enclosed Water Cooled
- Brushless, Permanent Magnet Excitation
- Grease antifriction bearings
- 2 Bearing RTD's
- Winding RTD's (2/phase)
- 3 Current Transformers
- Expected Noise ~ 85 dBa
- Space Heaters

Steam Turbine Generator Control System for Medium Voltage Generator

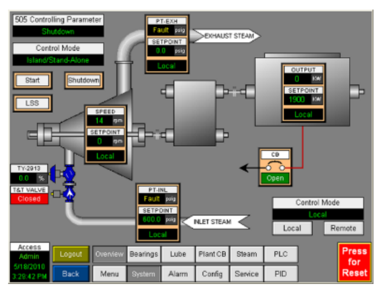
AirClean's Turbine Generator Control System incorporates turbine control, auto synchronizing, steam pressure control, optional temperature and pressure monitoring and generator/intertie protection into a single fully-integrated cogeneration control system designed to operate in parallel with utility power. The controls incorporate all the control features needed to operate a cogeneration system that maximizes efficiency and is easy to use.

Operator Interface

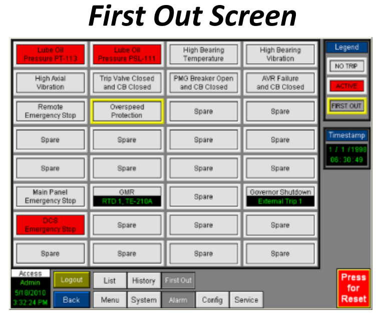
10-inch widescreen color touchscreen Operator Interface Terminal (OIT). The following screens are typical.

- Directory screen and other screens required for OIT navigation
- System overview screen showing system status, control mode and a summary of operating parameters
- Startup
- Shutdown
- Process control
- Overspeed test
- Screens for set points for control and monitoring parameters
- Service screens for PID tuning with real time trending
- Alarms and shutdowns

Overview Screen



First Out Screen



Turbine Control

- Controlled start sequence with manual override
- Exhaust pressure control
- Turbine output limiting to prevent over-powering the generator

Your AirClean Representative:
Dave Salem
Brad Thompson Co
Phone: (206) 619-3920
daves@bradtco.com

Turbine Protection and Monitoring

- Electronic overspeed protection
- Turbine trip relay, de-energize to trip
- Overspeed trip
- Customer trips
- Emergency stop pushbuttons
- Turbine speed
- Exhaust pressure
- Bearing temperature
- Lube oil pump control
- Lube oil temperature and pressure monitoring

Generator Protection and Monitoring

- Schweitzer Engineering Laboratories SEL 700G utility-grade generator protection relay for complete electrical system protection including sync check (25), voltage (27/59), reverse power (32), loss of field (40), current imbalance (46), voltage controlled time overcurrent (51V), loss of PT fuse (60FL) frequency (81O/U) and many other functions.
- Relay settings and circuit breaker are not included, but are available at extra cost.

Auto Synchronizer

- Fully automatic synchronization with backup manual synchronizing
- Display of generator and bus frequency and voltage
- Synchroscope display

Your AirClean Representative:
Dave Salem
Brad Thompson Co
Phone: (206) 619-3920
daves@bradtco.com

Control System Components Enclosure

The control system is fully modularized into three separate panels that significantly reduce the installation time by utilizing high speed industrial communications cable.

- OIT/Processor Module
  - Connected to the turbine skid and power modules with a dedicated, high speed industrial communications cable.
  - Can be placed anywhere within 100 meters (325 ft.) of the turbine generator skid and power module, although we recommend placing it near the skid for operator convenience
  - NEMA 12 wall-mount enclosure, 120 VAC power required
- Turbine Module
  - Electronic overspeed protection to provide on-skid backup to mechanical overspeed protection
  - Bearing temperature connections
  - NEMA 12 enclosure factory mounted on the skid, 120 VAC power required
- Power Module
  - Generator protection relay
  - Digital power meter
  - Factory mounted in the circuit breaker enclosure or in a NEMA 12 wall-mount enclosure

Your AirClean Representative:
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Brad Thompson Co
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daves@bradtco.com

SUPPORT INFORMATION:

The following documentation will be supplied for the above equipment in PDF format. AutoCAD and 3D models are available upon request.

Drawing No.	Title
Mechanical	
Job # - COV	Notes, Legend, Drawing List & Equipment List
Job # - PID	Steam Turbine Generator P&ID
Job # - GAR	Turbine Generator General Arrangement
Job # - ANC	Anchor Bolt Installation
Job # - INS	STG Process Field Connections
Job # - LUB	Lubrication Skid General Arrangement
Job # - WIR	Terminal Block Wiring Diagram
Electrical	
Job# - INFO	Project Information Project Summary/Drawing List
Job# - SO	System Overview One-Line and Trip Logic Diagram
Job# - CP	Enclosure Main Control Panel
Job# - E	Electrical Schematics and Generator Protection Diagram

Click here to download a copy of AirClean's typical
High Efficiency Dual Pressure Steam Turbine Generator Drawings

Inspection and Testing

- Steam turbine casing hydro testing
- Major steam turbine material certificates
- Steam turbine rotor balance
- Steam turbine mechanical run test

Shipping Preparation and Painting

- Steam turbine internal parts are protected for storage up to six months from shipment
- Lubrication system internal parts are protected for storage up to six months from shipment
- Complete package will be surface prepared and painted

Your AirClean Representative:
Dave Salem
Brad Thompson Co
Phone: (206) 619-3920
daves@bradtco.com

PAYMENT SUMMARY:

Dual Pressure Steam Turbine Generator Price $1,300,000

Commissioning and Startup Assistance (Qty. 2, 4 day trips) $21,500

Progress Payments:

Payment Terms	Equipment Only	Weeks ARO/Release
Purchase Order*	10%	0
Mechanical Drawing Submittal	15%	10-12
Control System Drawing Submittal	15%	12
Eight weeks prior to shipment	30%	30
Upon Readiness to Ship	20%	36-40
Upon Startup/Commissioning	10%	44-50

** The steam turbine is a long lead time item and will be released for fabrication upon receipt of order. If client requires approval drawings prior to release to manufacturing the lead time for fabrication and delivery will be extended.*

All invoices submitted are payable net 30 days. Factory inspections are permitted, with prior schedule.

Freight: DDP Jobsite

Validity: 30 days

Your AirClean Representative:
Dave Salem
Brad Thompson Co
Phone: (206) 619-3920
daves@bradtco.com

INSTALLATION ESTIMATE:

In addition to our standard equipment scope of supply, AirClean can provide installation services. In general, the following scope is required to provide an installed steam turbine generator system at an existing steam plant:

Item	Description
Freight/Insurance	Insured cost to transport all equipment to the site.
Offloading	Depending on site requirements, a crane or heavy-lift forklift will be required to offload the equipment at the site, and is included in this scope.
Steam Pipe Connections	Includes "T" into the inlet and exhaust pipe systems. This code welded pipe will be installed with proper pipe supports and expansion joints, as necessary. Standard industrial insulation and cladding will be included. Manual shutoff valves are used for isolation, as necessary. We have assumed 75 ft to high pressure steam and 75 ft to low pressure steam header connections.
Drain Pipe Connections	Typically socket-welded or threaded connections will be used to run drain pipe for all turbine drain connections.
Cooling Water Pipe Connections	Threaded cooling water pipe will be delivered from the customers cooling water system to provide bearing and possibly generator cooling water, if necessary.
Steam Turbine Generator Foundation	A flat pad or raised pedestal will be provided, depending on steam turbine size, to provide appropriate foundation support for the steam turbine, gearbox and generator.
Control Panel Foundation	A small, flat pad is necessary to support the local control panel, which will be provided as part of the installation scope.
Circuit Breaker Foundation	The circuit breaker will be installed in an existing MCC room, and the space and foundation are assumed to be adequate for the new circuit breaker.
Conduit & Conduit Trays	Sufficient conduit for the control wiring as well as the low voltage and medium voltage power wiring will be provided.
Control Wiring	Supply and installation of control wiring from the steam turbine generator skid to the control panel, and from the control panel to the circuit breaker will be provided. Checkout of the wiring will be provided as part of the startup and commissioning services.
Low Voltage Wiring	Any single phase power required to support generator heating and auxiliary equipment will be provided from the customer supplied MCC room.
Low Voltage Wiring	Power cabling between the generator and circuit breaker will be provided.
Interconnect Engineering	An interconnect agreement is typically required by the local utility. This agreement will generally take 4-9 months and will require power distribution engineering, which is included in this estimate. Modifications to the customer's power distribution system resulting from this study (if necessary), is NOT included in this estimate.
GPR Testing	The Generator Protection Relay supplied in the AirClean control panel will need to be tested before power is delivered to the customer from the new generator. AirClean will provide the GPR testing protocol, as well as the GPR testing.
Cold / Hot Alignment	Field alignment of the steam turbine generator will be required. Testing to assure steam pipe nozzle loading is below maximum steam turbine limits is included.
Steam Blows	Steam pipe blows are required to assure clean steam is delivered to the turbine. Often several days of steam blows are required. AirClean will supervise the steam blow activity.
Boiler Operation Interface / Training	AirClean will provide site management to interface with the boiler operators to assure smooth startup and transition to steam turbine generator operation. One-Day Operator Training will be provided.

Installation Time Estimate.. 8 – 10 weeks

Installation Cost Estimate... ~$300,000

Note: The above information is provided for reference only, and is not intended to be a complete or all-inclusive specification for installation requirements. A range of values is provided until a detailed site assessment can be made to determine specifics of the individual site requirements.

Your AirClean Representative:
Dave Salem
Brad Thompson Co
Phone: (206) 619-3920
daves@bradtco.com

STG COMMISSIONING:

AirClean's primary responsibility and scope during commissioning is the mechanical, instrumentation, and control checkout of the supplied STG skid and associated equipment. AirClean will assist where possible with electrical phasing verification and checkout. Tasks listed below provide a general framework for commissioning duties and may not necessarily be completed in the order listed.

Tasks Completed by Customer (Equipment Only Contract)

- Complete installation of turbine skid and customer steam piping to allow pipe steam blows.
- Perform initial steam blows per pipe blow down procedure in NEMA SM-24, including discharge piping for back pressure turbines. Completed prior to AirClean final commissioning trip.
- Verify generator/breaker electrical phasing with AirClean assistance during pre-startup or commissioning trip.
- Supply generator protection relay settings and perform static testing prior to AirClean final commissioning trip. AirClean can upload supplied settings during pre-startup trip.

AirClean Pre-Startup Site Trip

- Verify skid installation, piping installation, and exhaust relief valve settings.
- Perform coupling cold alignment and pipe strain check.
- Inspect and clean turbine bearings/shaft, flush bearing housings and fill with oil.
- Manually verify trip mechanism and safety devices in good condition.
- Verify STG control wiring, inspect pneumatic and cooling water piping and connections.
- Stroke turbine throttle actuator with hand held signal generator and verify stroke length.
- Upload customer supplied Generator Protection Relay settings.

AirClean Final Commissioning Trip

- Electrical/wiring checkout of turbine control panel, breaker, and related electrical equipment.
- Momentarily close breaker to "bump" generator and confirm rotation.
- Verify all piping and safety devices, warm up turbine, conduct over speed and trip testing.
- Run turbine to rated speed and check all instrument values and inspect piping, valves, coupling, bearings, etc. for noise, leaks. Run for min 2 hours and check hot alignment.
- Close generator breaker and record/confirm electrical output and readings.
- Tune turbine throttle valve PID loop and hand valve open and closure.

Your AirClean Representative:
Dave Salem
Brad Thompson Co
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daves@bradtco.com

EXCLUSIONS:

The following items are not included in the scope of supply outlined in AirClean's proposal:

General

- Receiving and offloading turbine generator skid and associated equipment
- Spare parts (offered as options)
- Taxes, fees and permits other than duties associated with shipping the turbine from Germany

Piping

- All steam piping outside of the equipment
- All condensate and leak-off piping outside of the equipment
- All cooling water piping outside of the equipment
- All plant and instrument air piping / tubing outside of the equipment
- Supply of safety relief valves needed for over-pressure protection

Electrical

- All the connecting cables between the supplied equipment
- Lighting and communication system
- Motor control center for all electric motors and heaters
- Uninterruptible power supply (UPS) for the Turbine Control System and electric auxiliary oil pump
- Power transformer
- Settings for AirClean supplied generator protection relay (priced as an option)
- Testing of generator protection relay
- Neutral grounding resistor
- Surge protection

Instrumentation

- Cables for instruments between the skid mounted junction box and the local control room.
- Installation of loose supplied field instruments

Engineering

- Machinery foundation design
- Piping design
- Power distribution system design

Installation & Startup

- Machinery and auxiliary equipment installation, piping installation
- Initial lube oil fill, and flushing (as necessary)

Your AirClean Representative:
Dave Salem
Brad Thompson Co
Phone: (206) 619-3920
daves@bradtco.com

AGREEMENT: This Agreement is between customer ("**Buyer**") and AirClean Technologies, Inc. ("**Seller**").

TERMS: Buyer will make full payment thirty (30) days from date of invoice, unless otherwise specified in the quotation document. The terms listed are general terms for the sale of goods only. (See *FREIGHT* for payment of freight invoices).

LATE PAYMENT CHARGES: A 1-1/2 % monthly service charge will be added to Buyer's account on invoices not paid within net thirty (30) day terms.

PRICES: All prices are F.O.B. Seller's plant and do not include any applicable Federal, State, Local Sales or Excise Taxes or other surcharges unless specifically indicated.

PAYMENTS: remittances must be made to:
AIRCLEAN TECHNOLOGIES, Incorporated / PO Box 46017 / Seattle WA 98126 USA
If the financial condition or credit of the Buyer at any time shall, in the judgment of the Seller, not warrant shipment of products ordered, the Seller may at its option require full payment prior to shipment or refuse to ship.

DESIGN: The Seller reserves the right to make design improvements without notice.

CANCELLATION: The Buyer may cancel upon the written consent of the Seller, but the Seller is entitled to reasonable cancellation charges including but not limited to labor expended, materials obtained or expended, reasonable overhead and profit.

SPECIAL AND CONSEQUENTIAL DAMAGES: In no event shall the Seller be liable for any consequential or special damages arising from any breach of these terms.

SHIPMENT AND DELIVERY: Shipment dates are based upon the Seller's best estimate only. The Seller will exercise its best efforts to ship on schedule, but shall not be liable for any damages or loss caused by any delay in delivery, including but not limited to delay caused by strikes, floods, fires, accidents, inability to obtain sufficient materials or products from suppliers, inability to obtain sufficient labor, or any legislative, administrative or exclusive law, order, or requisition of the Federal Government or any State or Municipal Government or any subdivision, department or office thereof. All shipments are F.O.B. Seller's plant. The responsibility of goods lost or damaged in transit rests with the Buyer and any recourse you may have rests with the carrier. Seller will make reasonable efforts to use reputable carriers with adequate insurance, but is not responsible for any loss incurred in transit. The Buyer must file any claims with the carrier. Damage to the equipment in transit is not just cause for delayed or partial payment of Seller's invoice. Buyer may contract with **AIRCLEAN TECHNOLOGIES, INC. Service Department** which can provide qualified supervisory personnel to assist installation of the products supplied.

MODIFICATION OR ADDITION OF TERMS AND CONDITIONS: No modification, addition to, or waiver, of any of the terms and conditions stated herein shall be binding upon the Seller except by written consent of an authorized officer of the Seller.

ACCEPTANCE: Any order by the Buyer placed pursuant to a quotation is subject to written acceptance and acknowledgement by Seller in Seattle, WA. By placing an order, Buyer will be deemed to have assented to the terms & conditions stated herein.

CLAIMS: All claims for corrections or deductions must be made in writing within ten (10) days after delivery of goods. If no claim is made within ten (10) days, Buyer will be deemed to have accepted all goods.

FREIGHT: Charges will be collect or prepaid third party billing.

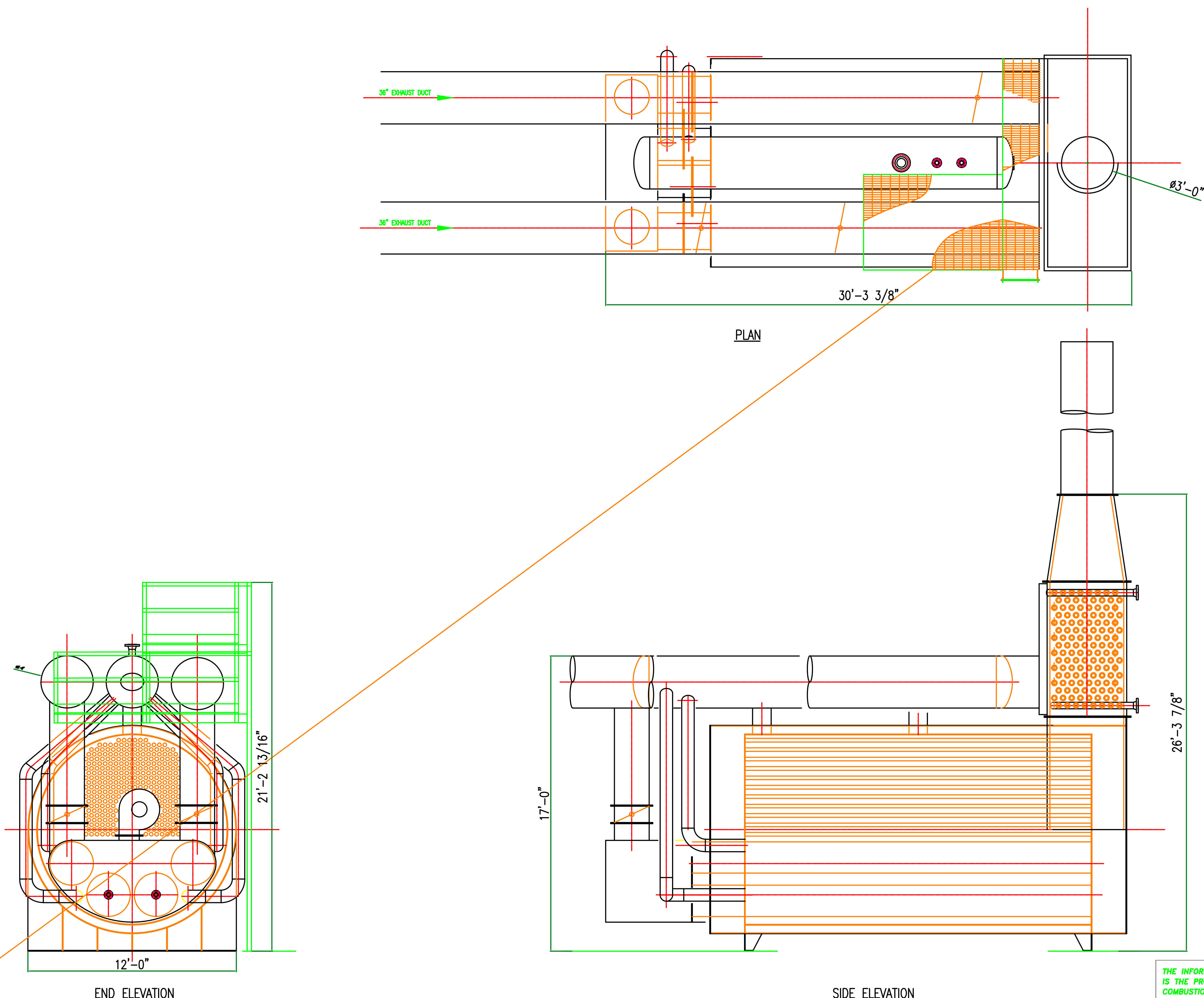
WARRANTY: Seller warrants the equipment of its manufacture against defects in workmanship (excluding corrosion and/or erosion related problems) and against defects in structural design for a period of one (1) year from the date of installation or eighteen (18) months from date of shipment whichever comes first. This warranty covers the product except for the turbines, generators, gearboxes, actuators, etc, which are not manufactured by Seller**.** Seller will pass on to Buyer the manufacturer's guarantee on such component equipment, if any. Seller will repair or replace (at Seller's option) F.O.B. point of original shipment, or refund the purchase price of any parts proven to be faulty material or workmanship. The maximum liability under this warranty is the purchase price of the defective part. This warranty does not cover trucking, handling, storage, or installation damage at the jobsite or problems created through improper or incorrect installation/operation.

WARRANTY CONDITIONS: This warranty is effective only if the following conditions are satisfied: (1) System conditions do not exceed the maximum System operating conditions; (2) The unit has never been subject to conditions or used other than those for which it has been designed; (3) The unit has not been in contact with abrasive or corrosive media or subjected to electrolytic action; (4) The unit has not been modified or remodeled by others after shipment.

WARRANTY DISCLAIMER: EXCEPT FOR THE LIMITED WARRANTY PROVIDED HEREIN, SELLER MAKES NO WARRANTIES (EXPRESS OR IMPLIED) WITH RESPECT TO THE PRODUCTS AND DISCLAIMS ALL IMPLIED WARRANTIES, INCLUDING FOR MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, TITLE AND NON-INFRINGEMENT. This warranty is expressly in lieu of all other warranties, either expressed or implied unless agreed to in writing by an authorized officer of the Seller.

GOVERNING LAW; VENUE AND JURSIDICTION: This Agreement will be governed by the laws of the State of Washington, without reference to its rules governing choice of law. The parties hereby irrevocably consent to the exclusive jurisdiction and venue of the federal and state courts located at King County, Washington with respect to any claims, suits or proceedings arising out of or in connection with this Agreement.

Appendix E – HRSG



THE INFORMATION ON THIS DRAWING IS THE PROPERTY OF TULSA COMBUSTION LLC, UNAUTHORIZED USE IS FORBIDDEN.

Tulsa Combustion LLC

CUSTOMER	UNIVERSITY OF MONTANA
P.O.	
USER	
JOB SITE	

GENERAL ARRANGEMENT
HRSG SYSTEM LAYOUT

DR. mc	CK.	APPR.
DATE: 10/3/16	DATE:	DATE:

SCALE: NONE
DWG. NO.: TC-16-09-1992-201-Q01
REV. 0

DWG. NO.	REFERENCE DRAWING	NO.	REVISION	DR.	CKD.	APPR.

Office/Shop
P.O. Box 702274
2300 S. Adams Road
Sand Springs, OK 74063
U.S.A.

Contacts:
Ph: 918-215-1900
Fax: 918-215-1908
E-mail: sales@tulsacombustion.com
Web site: www.tulsacombustion.com

Rick DeMarinis, PE
Principal I Energy Services Director
o 406.324.7382 | c 406.431.9495

Ref: University of Montana Boiler
TC-16-09-1992-Q01

Gentlemen:

Tulsa Combustion is pleased to offer a 50,000 pound per hour boiler for your consideration. We are designing the boiler to fit in the space made available by the planned removal of one of your older boilers. Tulsa Combustion is proposing the supply of the complete heat recovery system from the turbine outlets through the boiler, including the turbine exhaust bypass with muffler and a single stack for either the boiler or bypass mode of each turbine.

Our boiler will make 29,000 lbs/hr of 200 psig saturated steam using only the waste energy available from the turbine exhaust. The boiler can make 50,000 lb/hr with supplemental firing of the turbine exhaust gas or by firing with ambient air. The Tulsa Combustion Advection type boiler provides a much higher efficiency than is possible with a duct burner fired boiler. An important efficiency difference is that the boiler burners fire into a water-cooled radiant section providing higher efficiency in the co-firing mode. This allows the exit O_2 to be reduced to 3% at the maximum firing conditions. The Tulsa Combustion Advection boiler design is detailed in the data sheets that follow.

The attached drawing illustrates the turbine exhaust ducting and boiler design. The boiler is 12 feet in diameter and approximately 24 feet long. The boiler down comers and burner add to this length but are removable for shipment. The 3 foot diameter by 20 foot-long drum installs above the boiler. The Tulsa Combustion Advection boiler uses 3 passes. The first pass is comprised of four fire tubes, two pairs which are connected to each one of your turbine exhausts. The second pass is through nominal 2 inch pipe boiler tubes. The third pass is a flue gas passage in a gap between the boiler shell and an outer advection shell. The advection shell is internally lined with ceramic fiber. This pass also acts as a silencer. A breeching is provided on the advection shell to direct the flue gases up and through a convective economizer. Adjoining the flue gas breeching for the flue gases is a passage for the turbine exhausts to bypass the boiler and economizer. The bypass flow section is muffled to attenuate the turbine exhaust noise. The breeching, economizer, bypass common stack are lined with ceramic fiber insulation.

Tulsa Combustion has elected to provide a separate ducting for the exhaust of each of the turbines. This arrangement simplifies the ducting and provides for more efficient operation. With this arrangement, greater efficiency can be achieved by only firing one set of fire tubes.

This arrangement will facilitate higher thermal efficiencies when firing less than full co-firing rates as well as continued operation if one of the turbines needs to be out of service.

The Advection boiler and ducting are designed to operate within the allowable back pressure available from the turbines. A combustion air blower is provided to supply air for up to a 100% ambient boiler operation. The Combustion air blower will have a 40 HP, 460v/3Ph/60 Hz motor. Combustion air flow will be controlled by VFD motor speed control. Dampers are provided on the combustion air ducts to direct flow to only fire tubes requiring supplemental or ambient air operation.

A ladder and platform is provided to access the elevated steam drum and instruments and controls.

The Tulsa Combustion Advection Boiler offers a superior solution to fit into your available space and to meet your defined operations. The fire tube arrangement for turbine exhaust heat recovery with or without supplemental firing is far more compact than a duct burner-fired heat recovery boiler system. The Advection boiler exceeds the thermal efficiency offered by the large duct burner fired heat recovery boilers. We believe the Advection boiler represents the best option to meet your turbine exhaust and space limitation while producing up to 50,000 lb/hr of 200 psig saturated steam. The Tulsa Combustion pricing for our complete boiler system including turbine exhaust ducting and stack follow in the commercial section of this proposal.

Best Regards,

Mitt Chinsethagid
Sales manager

CC: Dave Salem – Brad Thompson Co.

Attachments: TC-16-09-1992-201-Q01 GA Drawing

INDEX

1. Boiler Data Sheet

1	Service	HRSG	Tag No.		
2	Boiler Type	ADVECTION	No. Boilers	ONE	
3			Model No.	TCLLC-AB-HRSG-XXX	
4	Package / Field Erected	PACKAGED	Indoor / Outdoor	INDOOR	
5			**DESIGN DATA**		
6	Maximum Continuous Rating (MCR)		50,000	LBS/HR	
7	Maximum Steam Flow		50,000	LBS/HR	
8	Turndown		0-100%	0% To 100% Of Maximum Steam Flow	
9	Minimum Load On Automatic Control		5000	LBS/HR	
10	Operating Steam Pressure		200	PSIG	
11	Operating Steam Temperature From Superheater		NA	°F	
12	Design Pressure		200	PSIG	
13	Design Temperature		400	°F	
14	Steam Purity Required		1	ppm (Dissolved solids)	
15	Maximum Allowable Pressure Drop Through Superheater		NA	PSIG	
16	Feedwater Temperature		240	°F	
17	Site Elevation			FT.(ASL)	
18	Special Characteristics Of The Application:				
19					
20					
21					
22					
23			**SCOPE OF SUPPLY**		
24	Boiler Pressure Parts	[X] Yes [ ] No	Feed Stop-Check Valve	[X] Yes [ ] No	
25	Burner(s)	[X] Yes [ ] No	Blowdown Valves	[X] Yes [ ] No	
26	Pilots	[X] Yes [ ] No	Piping To Blowdown Valves	[X] Yes [ ] No	
27	Forced Draft Fan	[X] Yes [ ] No	Auto. Blowdown Control	[X] Yes [ ] No	
28	Forced Draft Fan Motor Drive	[X] Yes [ ] No	Feedwater Regulator	[X] Yes [ ] No	
29	Forced Draft Fan Turbine Drive	[ ] Yes [X] No	Feedwater Reg. Bypass	[X] Yes [ ] No	
30	Forced Draft Fan Gear	[ ] Yes [X] No	Non Return Valve	[X] Yes [ ] No	
31	Forced Draft Fan Damper	[X] Yes [ ] No	Combustion Controls	[X] Yes [ ] No	
32	Air Ducts	[X] Yes [ ] No	Flame Safety Control	[X] Yes [ ] No	
33	Gas Ducts (Flue Gas)	[X] Yes [ ] No	Panelboard	[X] Yes [ ] No	
34	Carbon Monoxide Gas Ducts	[ ] Yes [X] No	Boiler Outlet Damper	[X] Yes [ ] No	
35	Superheater	[ ] Yes [X] No	Furnace Draft Regulator	[X] Yes [ ] No	
36	Economizer	[X] Yes [ ] No	Lifting Lugs	[X] Yes [ ] No	
37	Air Preheater	[ ] Yes [X] No	Prime Paint	[X] Yes [ ] No	
38	Steam Coil Air Heater	[ ] Yes [X] No	Final Paint	[X] Yes [ ] No	
39	Sootblowers With PV & F	[ ] Yes [X] No	Field Erection Labor	[ ] Yes [X] No	
40	Sootblower Wall Boxes Only	[ ] Yes [X] No	Erection Superintendent	[ ] Yes [X] No	
41	Stack	[X] Yes [ ] No	Startup Engineer	[X] Yes [ ] No	**PER DIEM**
42	Stack Lining	[X] Yes [ ] No	Hydrostatic Test	[X] Yes [ ] No	**Shop**
43	Platforms, Stairs & Ladders	[X] Yes [ ] No	Casing Pressure Test	[ ] Yes [ ] No	**NA**
44	Safety Valves	[X] Yes [ ] No	Factrory AcceptanveTest (Shop)	[X] Yes [ ] No	
45	Water Column	[X] Yes [ ] No	Boilout And Dryout	[ ] Yes [X] No	
46	Gauge Glass	[X] Yes [ ] No	Domestic Freight	[ ] Yes [X] No	
47	Steam Gauge & Piping	[X] Yes [ ] No	Export Packing	[ ] Yes [X] No	
48	Others (Specify)		Ocean Freight	[ ] Yes [X] No	
49					
50					
51					
52					
53					

54	**FUELS**								
55	GAS			OIL N/A			TURBINE EXHAUST		
56	LHV	1000	BTU/SCF	LHV		BTU/LB	TEMP	950	F
57	HHV		BTU/SCF	HHV		BTU/LB	LBS/HR	67933 each	
58	Press. @ Burner	30	PSIG	Press. @ Burner		PSIG		135,866 total	
59	Temp. @ Burner	40-80	°F	Temp. @ Burner		°F			
60	Mol. Weight	18		Viscosity		cP			
61				Atomizing		PSIG			
62									
63	Analysis		VOL. %	Analysis		WT %	Analysis		wt%
64							CO_2	4.02	
65							H_2O	7.09	
66							O_2	15.95	
67							N_2	71.45	
68							Ar	1.21	
69									
70									
71									
72	**MECHANICAL DESIGN**								
73									
74	Model No.	TCLLC-CF-200-50		Boiler Type	ADVECTION				
75	Boiler Surface	9649	FT^2						
76	Furnace Surface	628	FT^2						
77	Furnace Volume	393	FT^2						
78	Drums								
79	Steam: ID	36	IN	Length	120	IN	Volume	70.686	ft^3
80	Pressure Max	200	PSIG	Operating	200	PSIG			
81	Thickness Tubesheet	1	IN	Wrapper		IN			
82	Internals:								
83	Steam Purity		ppm						
84	Mud: ID		IN	Length		IN	Volume		ft^3
85	Furnace Tubes								
86	OD	2.375	IN	Wall Thickness	0.154	IN	C-C Spacing	3.75	IN
87	Material	SA53B							
88	No.	706							
89	Econonmizer Tubes								
90	OD	2.375	IN	Wall Thickness	0.154	IN	C-C Spacing	6	IN
91	Material	SA53B							
92	No.	128							
93	Type & Size Of Fins	Serrated 0.75" high, 0.040" thick, 6 fins/inch							
94	Screen Tubes								
95	OD	N/A	IN	Spacing		IN	No. Rows		
96	Superheater								
97	Type	N/A					Surface		m^2
98	Tube Material			Diameter		IN	Spacing		IN
99	Tube Spacer Material						Tubewall Thick.		IN
100	Temperature Characteristic								
101	Temperature Control								
102	Others (Specify)								
103									
104									
105									
106									
107									

108	**MECHANICAL DESIGN (continued)**					
109	Burner					
110	Manufacturer	TCLLC	Model	TCLLC-CF-200-50	Size	50000
111						
112	Heat Release: Normal	1.39E+07 BTU/HR	Maximum		4	Number of burners
113	Size & Type Of Pilots	ONE PER BURNER TCLLC HS-1				
114						
115						
116						
117						
118						
119	Stack					
120	Number	1	Self-Supported			
121	Location	OVER ECONOMIZER				
122	Material	CS			Thickness	IN
123	Top Inside Diameter	28" IN	Height	30 ft		
124	Lining Material	CERMIC FIBER				
125	Ductwork					
126	TEG Ducts:					
127	Material	CS				
128	Lining Material	CERMIC FIBER				
129						
130						
131						
132	Painting per:					
133	Specification:	TCLLC STANDARS			Total dry thickness:	3 MILS
134	System no.:	High Heat	Color:	Black		
135	Total Unit Weight:	160,000 lb	Boiler complete with economizer and turbine exhaust ducts			
136	Platforms, Stairs, Ladders:					
137		Steam Drum Access				
138						
139						
140	Combustion Controls:					
141		FULL BMS TO NFPA with SELF-CHECKING UV SCANNERS				
142		Firng Rate Controls				
143						
144						
145	Boiler Controls:					
146		Boiler 3 Element Drum Control				
147		ASME Section 1 required valves				
148		Continuous and Manual Blowdown				
149		Chemical Injection				
150	Air Pollution Control Measures:					
151		Low Nox burners				
152						
153						
154						
155						
156	**REMARKS**					
157						
158						
159						
160						
161						

2. Proposed Equipment:

Item 1: Tulsa Combustion Advection Boiler
One (1) Advection Boiler, ASME Section 1 Design, complete with:

- Four fire tubes for turbine exhaust flow and for supplemental or ambient air firing
- Fire Tube boiler designed for 29,000 lb/hr of 200 psig saturated steam with only turbine exhaust flow or for supplemental and/or ambient air firing for up to 50,000 lb/hr of 200 psig saturated steam.
- 36" diameter by 20 ft-long steam drum with internal demister steam separator
- Economizer
- Boiler controls and safety instruments
- Four Tulsa Combustion fire tube burners for supplemental/ambient air firing.
- BMS and firing rate controls for the burners.

Item 2: Turbine Exhaust Ducting
The following items are included:

- Ducting from each turbine exhaust discharge to two of the first pass fire tubes. The ducting includes damper for isolation of each turbine. The ducting is designed with expansion joint to handle the duct thermal expansion without loading the turbine discharge. Ducting and boiler pressure drop are engineered to be below the maximum back pressure recommended by the turbine manufacturer.
- Turbine exhaust ducting to bypass the boiler and economizer. This ducting connects to a muffled flow section adjoining the economizer box. Dampers are provided to direct the exhaust flow to the bypass or to the burners. The bypass ducting with its muffler are designed to allow for the maximum turbine exhaust flow without exceeding the turbine manufacturer's maximum.
- One stack for boiler operation or for turbine exhaust gas flow.
- Controls and instruments for ducting flow control and operation.

3. Drawings, Documents and Standards

The following customer deliverables are included in pricing:

	DRAWING/DATA	For Approval A	For Record B
1	Process Flow Diagram	A	B
2	Piping & Instrumentation Diagram	A	B
3	Engineering Drawings	A	B
4	System Plans & Elevations	A	B
5	Instrument List	A	B
6	General Assembly-Major Components	A	B
7	Foundation Plan & Anchor Bolt Layout	A	B
8	Inspection and Test Plan	A	B
9	Paint Procedures	A	B
10	General Description of System	A	B
11	Start-up/Checkout Procedures	A	B
12	Control Philosophy	A	B
13	Operating Manual	A	B
14	All Available Vendor Data		B
15	Specification Sheets	A	B

Pricing includes one submission, one review and return of documents incorporating all customer comments for submission A. Submission B will be for record only and not subject to review or modification within the original scope. Additional comments, format changes, additional documents are not included in the quoted price and will be supplied at the current professional rates and will be charged to the customer.

DEFINITIONS

1. Process Flow Diagram: A schematic representation of the process indicating state of the fluid at the input and output of each major component.
2. Piping and Instrumentation Diagram: A schematic representation of the process, based on the process flow diagram, indicating control, scope, functions, major interconnecting line sizes, and instrument locations (panel, field, etc.).
3. Engineering Drawings: Plan and Elevation with Member sizes and connection details
4. System Plans and Elevations: An orthographic depiction of the equipment indicating overall size of major components, plot area requirements, height and location of major components with respect to each other.
5. Instrument List: A list indicating type of instrument, tag number, location, and vendor.
6. General Assembly of Major Components: An orthographic depiction of each major component. This drawing will indicate overall dimensions, weight, connection locations, Nozzle legends, materials of construction and equipment features.
7. Foundation Plan and Anchor Bolt Layout: Orthographic depiction of foundation requirements including anchor bolt location and loading.
8. Inspection and Test Plan (ITP): Quality control document.
9. Paint Procedures: Document outlining surface preparation, paint materials and application methods.
10. General Description of the System: A short narrative describing the system.
11. Start-up/Checkout Procedures: A checklist utilized for initial system start-up and checkout.
12. Control Philosophy: A short narrative describing the control system.
13. Operating Manual: Checklists for normal start-up, shutdown, operation and emergency procedures.
14. All Available Vendor Data: All technical and maintenance data furnished to TCM by its component vendors.

15. Specification Sheets: The technical specifications that were used to purchase major components and instrumentation.

The following items are not included:
1. Calculations: TCM will perform calculations. They will not be subject to formal review.
2. Shop details/fabrication drawings
3. Foundation design
4. Wire and conduit schedules

The following items are to be provided by the customer unless otherwise specified in this proposal:
1. Shipment of all material from Point of Manufacture
2. Interconnecting piping, conduit and wire
3. Fuel and labor for cure of refractory (supervised by TCM)

CLARIFICATIONS*: STANDARDS FOR PROPOSED EQUIPMENT*
Unless otherwise specified in this Proposal, the following standards will apply to the proposed equipment:
1. WELDING: Per AWS Standards.
2. PIPING MATERIAL: A-106 or A-53B. Unless specifically called out in this proposal, piping 1.5" or smaller will be field-fabricated by others from materials supplied by TCM.
3. CARBON STEEL: A-36 or equal. A-500 for structural pipe
4. INSPECTION AND TESTING:
   a. The following items are not provided for:
      - Hydrostatic test
      - PMI
      - Hardness
      - Charpy tests
   b. The following tests will be performed:
      - X ray as required by ASME code calculations only
      - Hydro Tests as required by ASME code or B31.3

4. Project Schedule

Drawings for Approval: 3 to 6 weeks after the receipt of an order
Normal Shipment Time: 24 to 30 weeks after the receipt of approved prints
Improved Delivery: Please advise your requirements.

5. Pricing and Commercial Terms

Budget Pricing

Tulsa Combustion Advection Boiler System as noted above has a budget price of

US$ 900,000.00

Field Services

Tulsa Combustion can support the commissioning of the system and operator training. Rates for these services are per the Tulsa Combustion Professional Rate Schedule in this Proposal.

Payment Schedule

Payments required by Tulsa Combustion to keep the project in a neutral cash flow will be due according the completion of milestones as follows:

- 20% of purchase order value at time of order and due immediately
- 25% of purchase order value upon submittal of drawings by Tulsa Combustion and due net 15 days
- 40% of purchase order value upon submittal of unpriced purchase order for major material and due net 15 days
- 10% of purchase order value upon completion of fabrication and due net 15 days
- 5% of purchase order value upon notification equipment is ready to ship or shipment whichever occurs first and due net 15 days

Terms of Sale

Commercial terms will be as mutually agreed. Progress payments are required to keep Tulsa Combustion cash neutral. Tulsa Combustion's standard Terms of Sale appear on the following pages.

Tulsa Combustion LLC
Terms of Sale

1. **<u>LIMITATION OF LIABILITY</u>: UNDER NO CIRCUMSTANCES SHALL TULSA COMBUSTION BE RESPONSIBLE FOR LOSS OF USE/LOST PROFIT, INCIDENTAL, CONSEQUENTIAL, INDIRECT, OR SPECIAL DAMAGES, NOR SHALL TULSA COMBUSTION' TOTAL AGGREGATE LIABILITY UNDER THIS PURCHASE ORDER EXCEED THE VALUE OF THE PURCHASE ORDER.**

2. <u>WARRANTY:</u> Tulsa Combustion warrants the equipment of its manufacture to be free from defects in material or workmanship for 18 months after shipment or 12 months after first operation, whichever occurs first. Vendor-supplied items will carry the standard vendors' warranties, which will be transferred to the end user. This warranty shall be for the repair or replacement, at Tulsa Combustion' option, of any defective parts, Ex-Works (EXW) point of manufacture. All costs for labor, equipment, and/or material costs for removal and/or reinstallation of parts, are expressly excluded from this warranty. ALL WARRANTIES SHALL BE VOIDED, AND BUYER AGREES TO INDEMNIFY AND HOLD TULSA COMBUSTION HARMLESS FROM, ANY CLAIM OF LIABILITY BY ANYONE, IF: (1) ANY REPAIRS, ALTERATIONS, MODIFICATIONS, OR DISASSEMBLIES ARE MADE WITHOUT TULSA COMBUSTION' APPROVAL OR IN VIOLATION OF THE OPERATING MANUAL INSTRUCTIONS; (2) ANY REPLACEMENT PARTS ARE USED ON THE EQUIPMENT OTHER THAN THOSE SUPPLIED OR APPROVED BY TULSA COMBUSTION; (3) THE EQUIPMENT IS UTILIZED FOR ANY PURPOSE OR IN ANY MANNER OTHER THAN AS STATED HEREIN; OR (4) THE EQUIPMENT IS OPERATED OTHER THAN IN STRICT CONFORMANCE WITH THE OPERATING MANUAL, BY QUALIFIED PERSONNEL. The above warranty is the sole and exclusive guarantee and warranty provided by Tulsa Combustion, and all other warranties or guarantees (express, implied, in law, or in equity, including warranties of merchantability and fitness for a particular purpose) are hereby disclaimed and excluded. Tulsa Combustion' total aggregate liability with regard to warranties shall not exceed the order amount. Consumables, such as, but not limited to, bulbs, gaskets, thermocouples, refractory, etc. are specifically excluded from the above warranty. Warranties of purchased equipment will be pass through and will carry the term and conditions under which Tulsa Combustion purchased them.

3. <u>CHANGES:</u> Tulsa Combustion is dedicated to meeting the requirements of the Buyer's specifications. Many small changes may significantly affect both Price and Schedule. A high level of communication regarding the impact of changes is required to update the Buyer regarding the project status. A design freeze will be placed on the project prior to release for fabrication and the Buyer will be notified of this date. If Buyer desires to make changes in quantities or Goods or Work, in specifications or drawings governing the Goods or the Work, or otherwise amend or modify the Purchase Order, it shall deliver a Change Order to Tulsa Combustion. If, within 21 days, Buyer and Tulsa Combustion are unable to reach an agreement regarding changes in Price or time of delivery, this Purchase Order shall remain in effect as originally issued. Unless otherwise agreed in writing by the Seller, the time spent by the parties to evaluate the need for a Change Order as set forth above shall be automatically added to the time for Seller's delivery of the Goods or performance of the Work, without the need for a signed Change Order to such effect. Any change made after the design freeze may incur disproportionate cost and schedule impacts.

4. <u>PATENTS</u>: Under no circumstances, shall a patent infringement indemnity granted by Tulsa Combustion, if any, apply to any equipment, or any part thereof, manufactured to Buyer's design or to changes in Tulsa Combustion' design requested by Buyer. As to such equipment or part, Tulsa Combustion assumes no liability whatsoever for patent infringement. Further, such an indemnity, if any, will be expressly conditioned upon Buyer's agreement to promptly

notify Tulsa Combustion of any claim or suit or proceeding in which such infringement by Buyer is alleged, and Buyer shall permit Tulsa Combustion to control completely the defense or compromise of any such claim, suit, or proceeding, and Buyer shall render such reasonable assistance in the defense thereof as Tulsa Combustion may require.

5. <u>CANCELLATION:</u> Any Purchase Order resulting from this proposal may be canceled by Buyer for its convenience by giving Tulsa Combustion written notice of such cancellation. Upon receipt of such notice, Tulsa Combustion shall cease all of its own activity (except that related to the cancellation) and terminate under the most reasonably favorable terms all related subcontracts as soon after such cancellation as reasonably practicable. Buyer shall pay the greater of (a) 25% of total Purchase Order value, or (b) Tulsa Combustion' costs incurred for this Order to the point of cancellation, plus costs incurred in the termination of related subcontracts (including reasonable cancellation charges actually paid by Tulsa Combustion to its sub suppliers and reasonable costs incurred in preserving and protecting materials, work in progress, and completed goods), plus a reasonable allowance for overhead and profit on such costs, whichever is greater. However, in no event shall the amounts payable to Tulsa Combustion for cancellation under this paragraph exceed the total price of this Order, less payments previously made by Buyer to Tulsa Combustion under this Order. Upon receipt of Buyer's payment by Tulsa Combustion, title to all materials, work in process, and completed goods shall vest in Buyer, as-is, where-is.

6. <u>INFORMATION AND IMPROVEMENTS:</u> Tulsa Combustion agrees to supply drawings, specifications, and other data (collectively, "Information") to Buyer as provided herein. Buyer shall have the limited right to use such Information internally for the purposes of evaluating the equipment design, and operating, maintaining, and repairing the equipment, and shall have the right to reproduce such Information for these limited purposes. Buyer shall not be obligated to return to Tulsa Combustion any such Information. However, neither Buyer nor any other party is granted any other rights by this Agreement, including but not limited to rights to the designs of, or license to manufacture or have manufactured, the equipment or anything else contained or shown in such Information. Technical information and all other work products emanating from or developed by Tulsa Combustion or its agents or employees in connection with the Purchase Order, including but not limited to inventions, discoveries, and improvements, patentable or unpatentable, shall be Tulsa Combustion' sole and exclusive property and may be used or transferred by Tulsa Combustion in any manner it finds appropriate without restriction.

7. <u>INDEMNITY:</u> Under no circumstances will Tulsa Combustion indemnify buyer or any other party for claims or losses, which are not caused by the negligence or willful misconduct of Tulsa Combustion.

8. <u>ALTERNATE DISPUTE RESOLUTION:</u> If a dispute arises concerning or related to this Agreement, it is the express intent of the parties hereto that they commit to enter into good faith efforts to resolve the dispute at a meeting or meetings in which officials from both parties who have authority to settle the dispute shall participate. The purpose of such negotiations will be an honest effort to allow each party an opportunity to determine if the dispute is resolvable prior to expensive and lengthy litigation. The parties shall have complete discretion as to what procedures shall be used and what agenda shall be discussed. All parties shall hold any such negotiation or series of negotiations as confidential, and the parties hereto do commit themselves that they shall not disclose either the existence of such proceedings or the content thereof. Any participation in or initiation of such discussions shall not be deemed to be an admission of liability, and no statement made or provided in or related to such negotiations shall be construed as a statement against interest or otherwise disclosed or used in any proceeding involving the parties.

   If the dispute cannot be resolved at such meeting or meetings of senior officials, the parties agree to submit the dispute to non-binding mediation by a mediator mutually selected by the parties. If the parties are unable to agree upon a mediator, then the American Arbitration Association shall appoint the mediator. In any event, the mediation shall take place within thirty (30) days of the date a party gives the other party written notice of its desire to mediate the dispute.

The parties commit to commence these negotiations prior to litigation being filed (except for injunctive relief), but in no event shall they commence later than four (4) months after litigation is filed. If the party failing to participate in such meetings and mediation prior to litigation being filed is the party who filed the litigation, the party failing to participate in such meetings and mediation prior to litigation being filed shall be liable to the other party for the reasonable attorney fees and expenses of the other party for the reasonable attorney fees and expenses of the other party incurred in seeking a stay of the litigation pending the conclusion of such meetings and mediation.

6. Professional Rate Schedule

All rates are based on an 8 hr/day, Monday through Friday and exclude Holidays.

Principal Engineer: A principal engineer has a minimum of 30 years' experience and extensive testing, design, start-up and industry knowledge. The engineer will have been responsible for significant innovations and developments in their field. This rate applies to Roger Noble, Roger Witte, and Mike Keller.

Nominal Rate $200/hr

Senior Engineer or Senior Technician: A senior design engineer or technician has a minimum of 10 years experience including testing, design, start-up and trouble-shooting of process equipment and systems.

Nominal Rate $150/hr

Engineer or Technician: An engineer or technician has a minimum of 5 years of experience including testing, design and start-up of combustion systems.

Nominal Rate $125/hr

Associate Engineer or Junior Technician: An associate engineer or junior technician has a minimum of 2 years of experience including testing, design and start-up.

Nominal Rate $75/hr

Drafting Supervisor or Senior Design Draftsman: A Senior Design draftsman or Supervisor who has 10 years design experience in the design of combustion systems.

Nominal Rate $200/hr

Associate Design Draftsman: An associate design draftsman has a minimum of 5 years experience in design of combustion systems.

Nominal Rate $80/ hr

Design Draftsman: An associate design draftsman has a minimum of 2 years experience in design of combustion systems.

Nominal Rate $70 / hr

Shop rates: Combination rate for Shop Supervision and Scheduling, QC, Lead Men, Welders, Fitters, Helpers, Electrical, Controls/ Instrumentation, Purchasing, Shipping and Receiving efforts including all welding consumables, tools , overheads and burdens

Nominal Rate $78

Third party Charges

Crane and other special equipment rentals, third party inspection, x-ray and testing etc., will be billed at cost plus 10%.

Above rates include normal and customary secretarial and administrative services, use of computers and normal copying and plotting services. Extraordinary administrative charges will be billed at direct cost plus 10%.

Weekend and overtime rates are billed at 1.5 times the above rates. Holidays are billed at 2 times the above rates.

Material Charges

All material necessary to complete the job will be billed at cost plus 10%.

Start-up and Commissioning Assistance

Consultants for assistance and advice during start-up and commissioning of equipment are provided on the following basis:

A. Within the United States and Canada: (Prices in U.S. Dollars)
   1. $1,600 per day for up to 10 hours per day or portion of a day. Saturdays and Sundays not included.
   2. $215 per hour each additional hour.
   3. Saturdays and Sundays: $1,900 per day up to 10 hours per day. $265 per each additional hour.

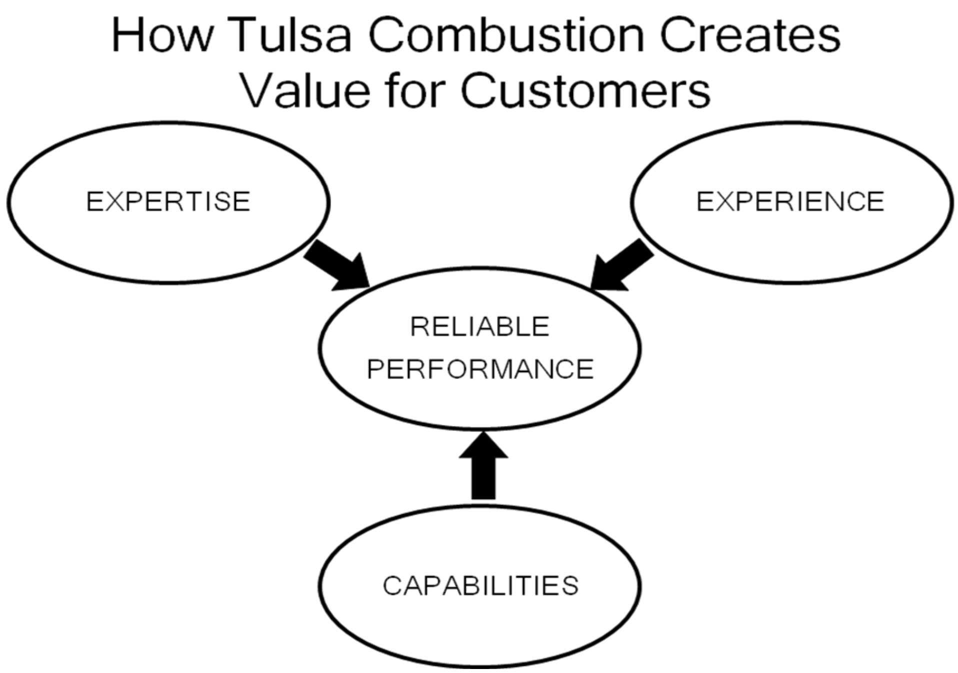
B. Outside the United States and Canada:
   4. $2,150 per day for up to 10 hours except Saturday and Sunday.
   5. $300 per hour for each additional hour.
   6. Saturdays and Sundays: $2,300 per day for up to 10 hours. $375 per hour for each additional hour.

C. Personnel act in an advisory role only. The above rates apply to work at site and travel time. Travel days will not be billed for overtime. All living and travel cost will be billed at actual cost. International travel will be on business class basis. Start-up and Commissioning rates for war-risk countries will be negotiated based on the level of exposure to possible injury or loss.

Invoicing

Invoices will reflect two weeks of charges, including time, materials and third party charges, and will be submitted BI-weekly for payment on receipt. The first week of the invoice will be actual charges and the second week will be estimated charges for the next week. The subsequent invoice will true up the estimated charges from the second week. All invoices will include copies of the invoices from our vendors as well as copies of time sheets of employees.

7. Tulsa Combustion's Qualifications



EXPERTISE

Technologies and Skills

- Process Efficiency Optimization
- Plant Economic Analysis
- Process Control Integrity
- Access to Industry Experts

Specialized Knowledge and Tools

- Knowledge of Industry Practices
- Manufacturing Engineering
- Project Management
- Field Installation

Reliable Systems

- Predictable Systems Performance
- Safe Project Execution
- Environmental Compliance
- Capital Cost Containment
- Operating Cost Minimization
- On-time Completion
- Superior Return on Investment

EXPERIENCE

History of Success

- Long-tenured Staff
- Staff Backgrounds in Industry
- Staff Roles in Industry
- Customer Collaboration

Successful Projects

- Reference Projects
- Global Reach
- Repeat Customer Engagements
- Organizational Learning

Predictable Investment

- Best-practice Design Strategies
- Optimal Technology Selection
- Competent Decision Support
- Proven Solutions
- Pragmatic Approach
- Flexible Scoping
- Regionalization
- Consistent High-level Support

CAPABILITIES

Resources

- Process & Controls Engineering
- Procurement & Logistics
- Project Management
- Strong Financial Position

Execution Capacity & Certification

- Internal Fabrication Facility
- Regional Partnerships
- Sea Port Access in Oklahoma
- Industry Standards Compliance

Smooth & Consistent Execution

- Reliable Project Completion
- Flexibility in Accommodating Customer Standards
- Single-source Simplicity
- Effective Functional Integration
- Superior Schedule Performance
- Appropriate Local Content
- Flat Organization for Ease of Decision-making and Access to Owners

Appendix F – Helical Pier Supports


PRO

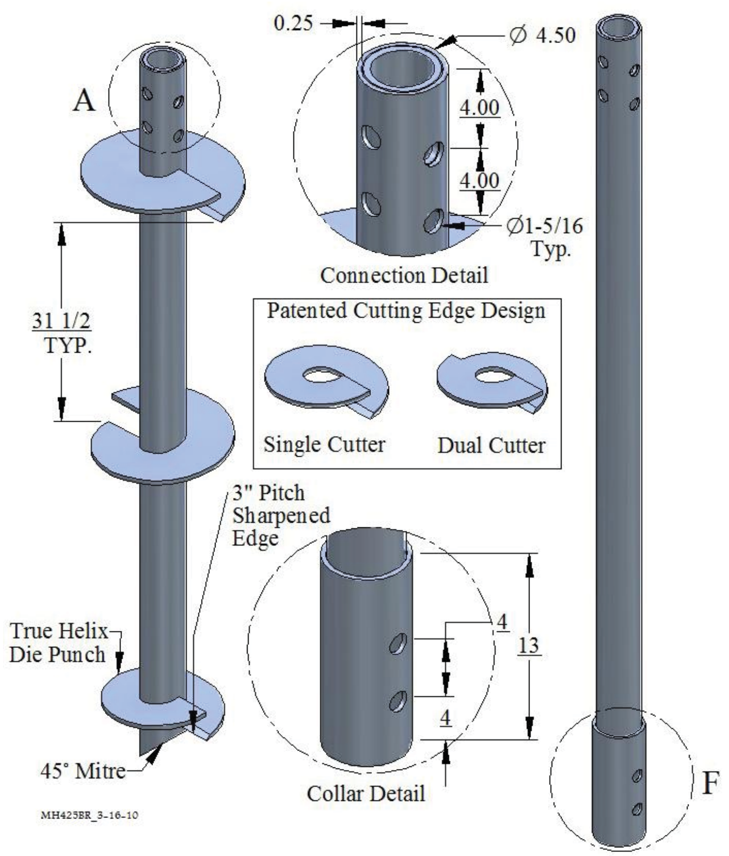
MAGNUM® MH425BR Helical Piles

80 Ton Ultimate - 40 Ton Allowable Capacity

High-Strength 4.50" Diameter, 0.25" Wall, Round-Shaft with
Reinforced (R) Dual Sleeve Coupler & (2) 1.25" Bolts

Description

Magnum MH425BR Helical Piles have 80 tons ultimate capacity and 40 tons working capacity in compression and tension. Lead sections and extensions couple together to extend helical bearing plates to the desired bearing stratum. Round shafts offer increased lateral and buckling resistance compared to solid square shafts. Capacity calculations are based on average life expectancy of over 50 years for most soil conditions. Patented Magnum Dual-Cutting Edge helical bearing plates (DCE) enhance penetration through dense soils with occasional cobbles and debris. Custom lengths and helix configurations are available upon request. See Magnum Technical Reference Manual for additional information including design tools, prescriptive specifications and example plans.



Lead - MHL425BR7M10S12S14SG

Extension - MHE425BR7G

STEEL SPECIFICATIONS	
SHAFT	HSS 4.50" x 0.25" wall ASTM A513 65 KSI, or Equivalent
I	7.33 in^4
Ag	3.24 in^2
S	3.27 in^3
COUPLING	0.31" Wall Collar with 0.375" Insert
BOLTS	(2) 1.25" Diameter SAE Grade 5 / ASTM A325
BLADES	0.625" Thick, Helix Die-Pressed ASTM A36, or Better
COATING OPTIONS	Hot-Dip Galvanized (G), Bare Steel (NG), Epoxy Powder Coated (EP)

PROPERTIES	
5.7 ft^{-1}	Ultimate Capacity-to-Torque Ratio
28,000 ft-lbs	Maximum Installation Torque
STRUCTURAL CAPACITY	
105 Tons	Ultimate Capacity
53 Tons	Allowable Capacity
CAPACITY BY TORQUE	
80 Tons	Ultimate Compression & Tension
40 Tons	Allowable Compression & Tension

Note: Helical piles shall be installed to appropriate depth into suitable bearing stratum as determined by geotechnical engineer or local practice. Capacity by torque is based on advancing pile to maximum installation torque. A minimum factor of safety of 2.0 is recommended for determining allowable capacity from correlations with final installation torque. Deflections of 0.05" to 1.0" are typical at allowable capacity. A higher factor of safety may be required for tolerable deflections. For tension capacity, helical bearing plates must be deeply embedded. Load tests are recommended when practical.

4.5" Product Line Helical Bearing Plate Specifications & Available Configurations

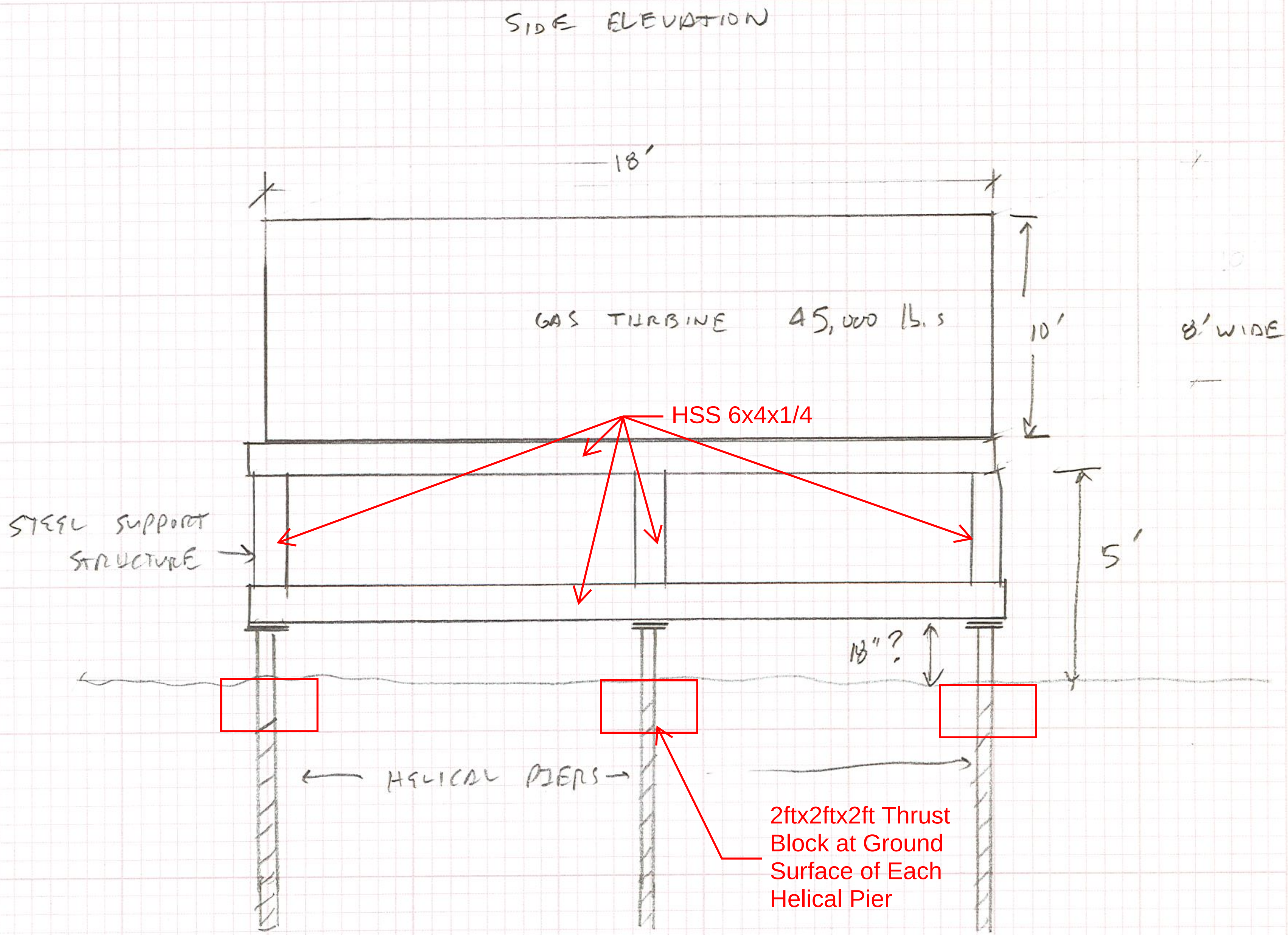
0.625" Thick; ASTM A36 or Higher
3.00" Blade Pitch
10", 12", 14", 16" Diameter
Standard Circular Helix, or
Patented Dual Cutting Edge Helix
Sharpened Edges - All Helix
*5 ft. Lead or Extension - up to 2 helical bearing plates
*7 ft. Lead or Extension - up to 3 helical bearing plates
*10 ft. Lead or Extension - up to 4 helical bearing plates
*15 ft. Lead or Extension - up to 6 helical bearing plates
** Standard Stocking Length*

All Magnum Steel & Products Made in U.S.A.

Magnum Piering, Inc.
6082 Schumacher Park Dr.
West Chester, OH 45069
800-822-7437
www.magnumpiering.com

CTA

Subject: Turbine support
Project No.:
By:
Page: 1 of
Project Name: U. of M Combined Heat & Power Project
Date: 9/26/16



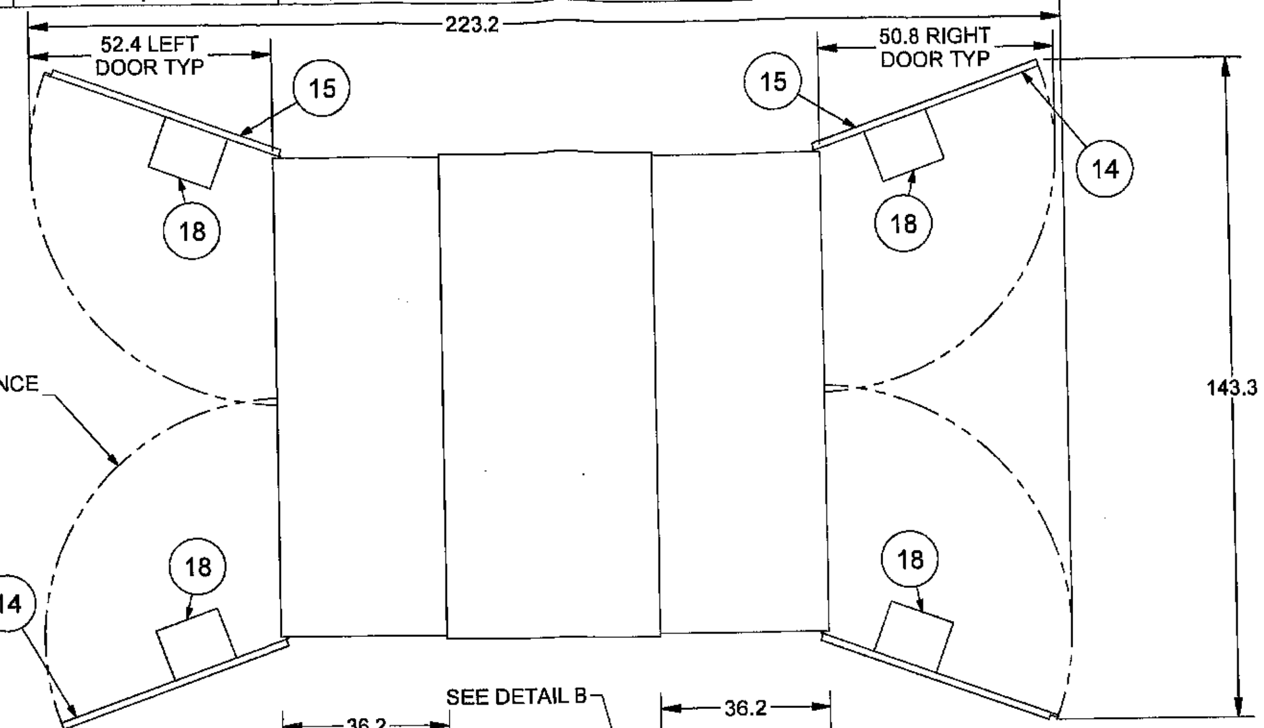
316 North Last Chance Gulch Helena, Montana 59601 • 406.495.9400 Fax: 406.495.9403
www.ctagroup.com • info@ctagroup.com

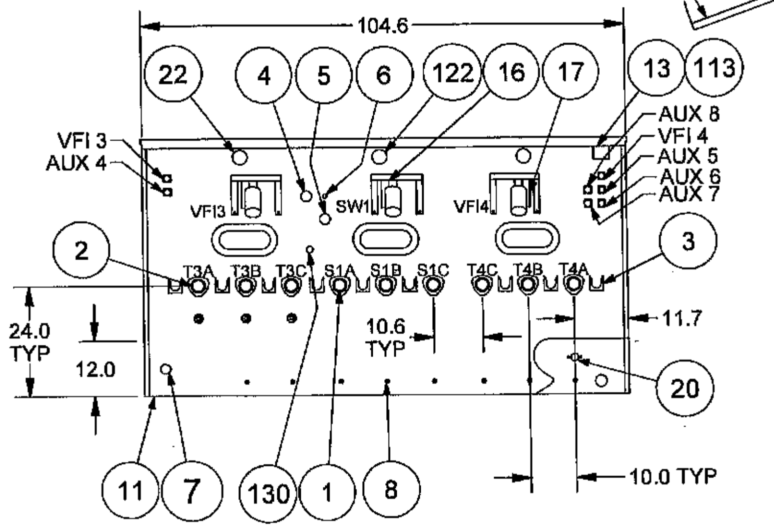
Appendix G – Existing UM Primary Switchgear

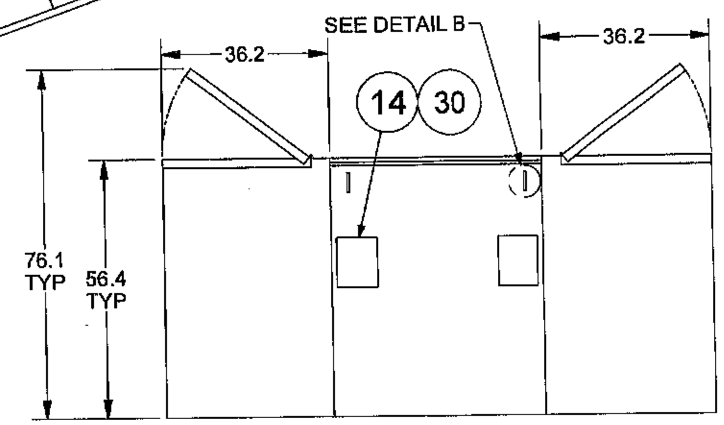
ITEM	DESCRIPTION	QTY
00	UNIT IS FILLED WITH ENVIROTEMP 200 FLUID	
01	15 KV 600 AMP SOURCE BUSHING - ALUMINUM	6
02	15 KV 600 AMP TAP BUSHING - ALUMINUM	12
03	STANDOFF BRACKET - STANDARD	18
04	1" FLUID FILL PLUG	1
05	FLUID SIGHT GAUGE	2
06	PRESSURE RELIEF VALVE	1
07	1" FLUID DRAIN PLUG WITH 3/8" SAMPLER	1
08	SS GROUND NUT, 1/2" - 13 UNC	18
09	RECESSED LIFTING LUG	4
10	MOUNTING CLEAT	4
11	REMOVABLE SILL	2
12	BOLTED TOP COVER	1
13	NAMEPLATE ON FRONT PLATE	1
14	PHASE DIAGRAM ON INSIDE OF DOOR	6
15	TWO SIDE HINGED DOORS WITH SS HINGES, DOOR STOPS, RECESSED PENTA-HEAD DOOR BOLT & PADLOCK PROVISIONS AND HINGED FLIP TOP CAB. COVER INTERLOCKED WITH DOORS.	2
16	15 KV 3PH VACUUM SWITCH WITH MOTOR OPERATED PROVISIONS AND WITH 2 "a" & "b" AUXILIARY SWITCH CONTACT(S) FOR USER MONITORING	2
17	15 KV 3PH VACUUM FAULT INTERRUPTER (VFI) WITH MOTOR OPERATED PROVISIONS AND WITH 2 "a" & "b" AUXILIARY SWITCH CONTACT(S) FOR USER MONITORING	4

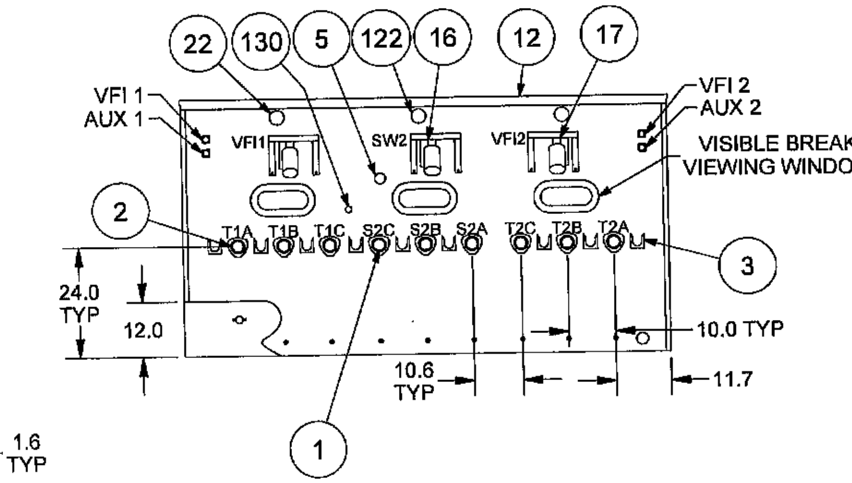
ITEM	DESCRIPTION	QTY
18	iDP-210 RELAY VFI CONTROL	4
20	COVERED PROVISIONS FOR FAULT INDICATORS	18
22	SEMAPHORE - 1 PER VFI	4
30	SIDE MOUNTED-SIDE OPERATED VISIBLE BREAK	4
113	NAMEPLATE - P.T. VOLTAGE	1
122	SEMAPHORE - 1 PER VACUUM SWITCH	2
130	FRONT MOUNTED-FRONT OPERATED VISIBLE BREAK	2

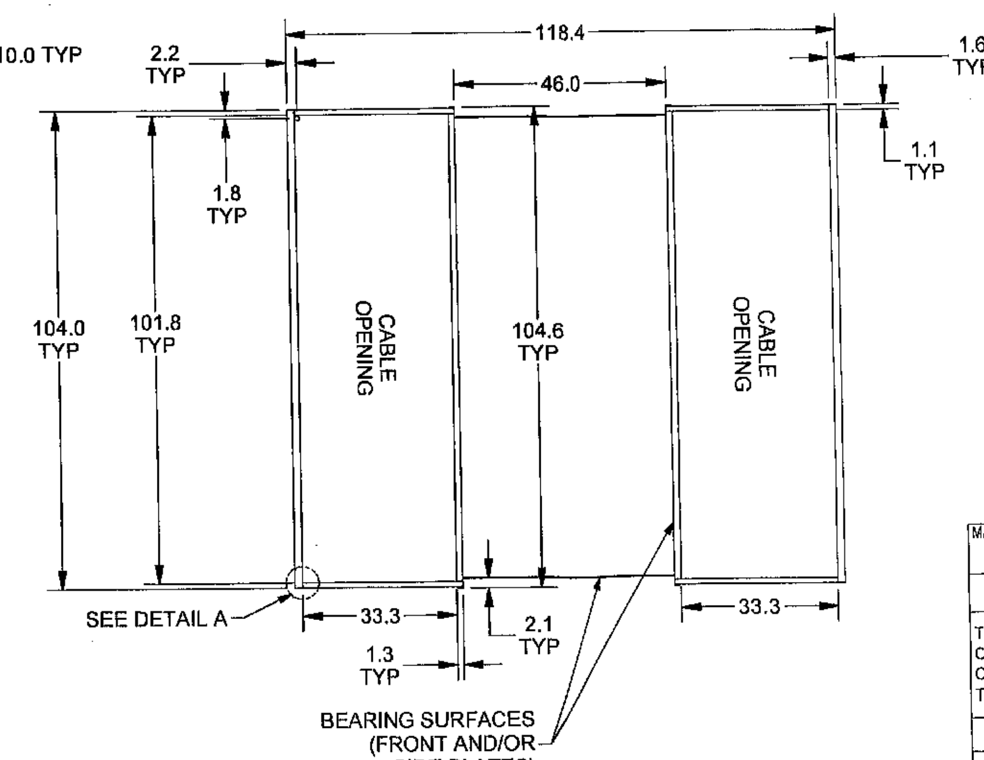
Heating Plant VFI

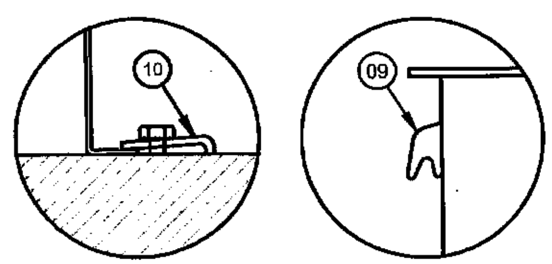






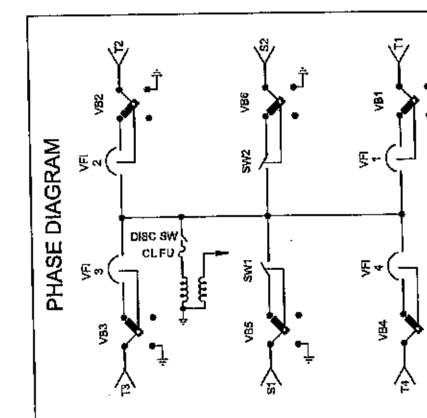






DETAIL A

DETAIL B



NOTES:
1. UNIT HAS IEEE/ANSI TAMPERPROOFING.
2. UNIT WEIGHT = 8800 LBS.
3. TWO E-200 DECALS ARE INSTALLED ON UNIT, ABOVE FLUID FILL PLUG AND FLUID DRAIN PROVISIONS.
4. THREE 7200:120 PTs CONNECTED TO COMMON BUS; SYSTEM CONFIGURATION: GROUNDED WYE.
5. AUX 6, 7 & 8 CONNECTOR ON FRONTPLATE INCLUDES PLUG BODY ASSEMBLY, CABLE RANGE FOR PLUG BODY ASY .812 TO .937 DIA. SEE SCHEMATIC (LATER) FOR USER CONNECTIONS TO AUX. SWITCHES.

REV	DATE	BY	EC NO.
00	07/25/2016	CDA	
CHECKED BY: ACS	DATE: 7/29/16		

MATERIAL: MILD STEEL W/ NON-CORROSIVE HARDWARE

ALL DIMENSIONS ARE IN INCHES [MM]

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THIS DRAWING HAS BEEN GENERATED FROM A 3D MODEL

EATON Powering Business Worldwide

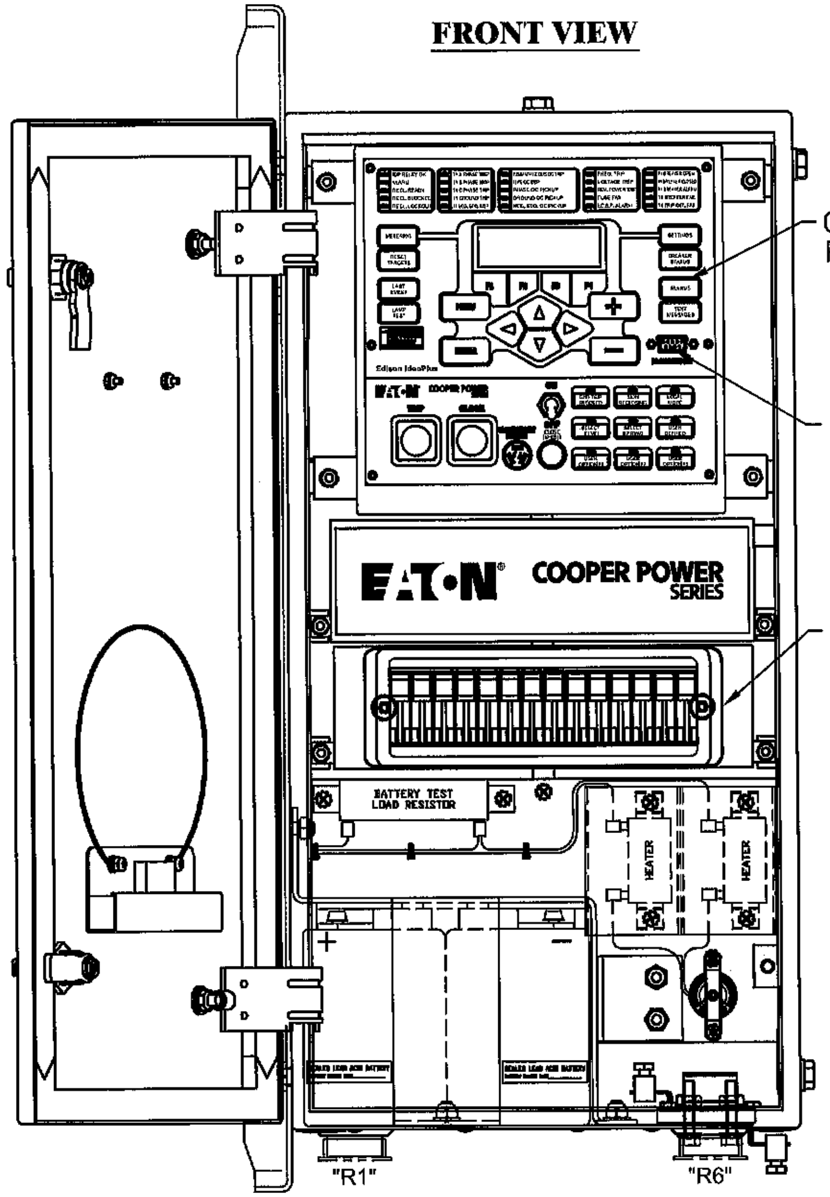
TITLE: OUTLINE DIMENSIONS

DESC: **COOPER POWER SERIES**
OUTLINE DIMENSIONS
3PH 8.3/14.4 PADMOUNT SWITCHGEAR

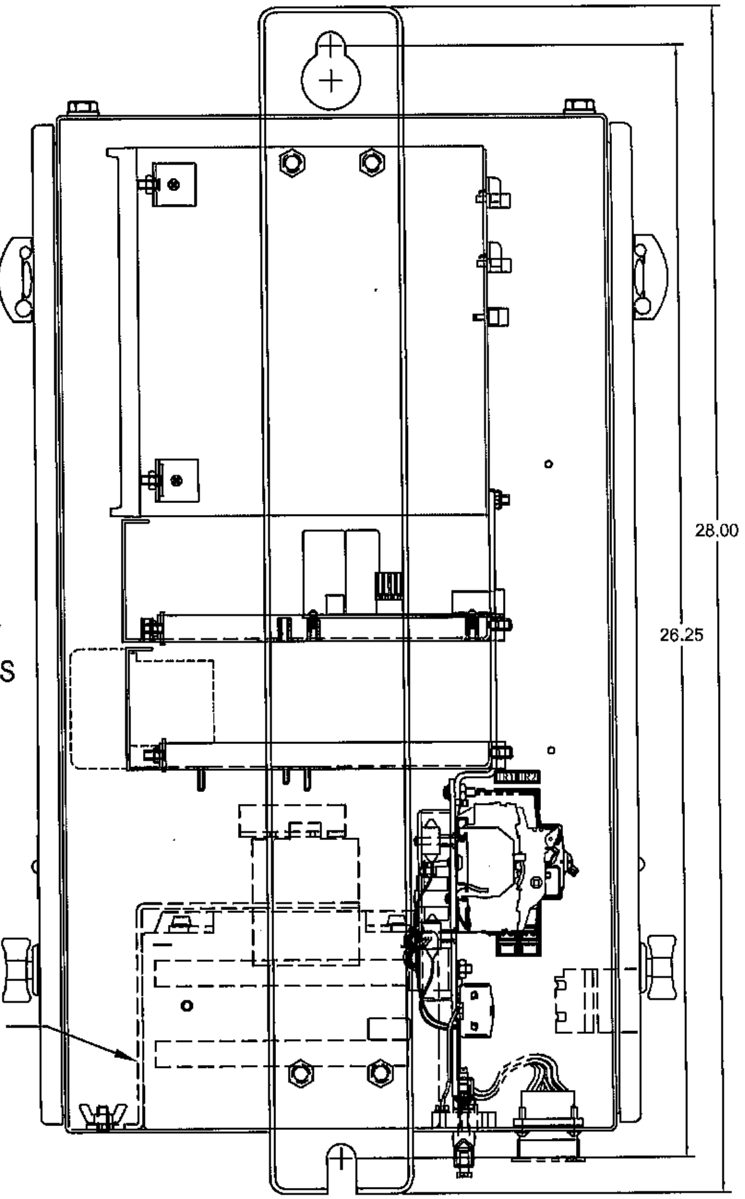
DWG:	DATE:	REF:	SHEET #:	SCALE:	REV:
PKP	07/25/2016		1 OF 1	NTS	00

P220612L15S06M

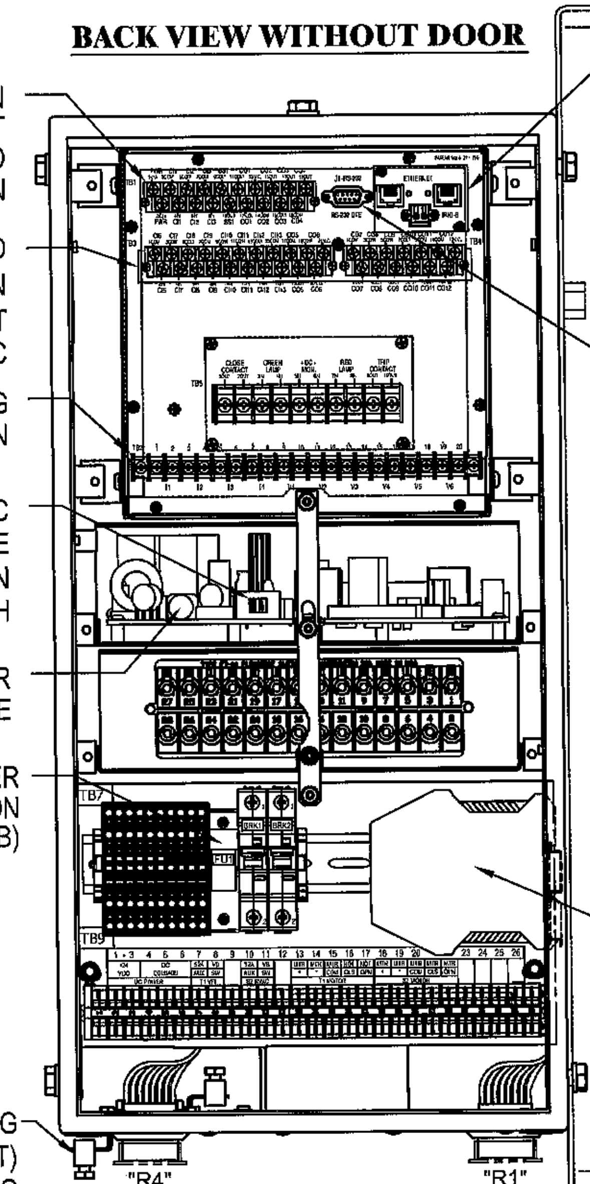
FRONT VIEW

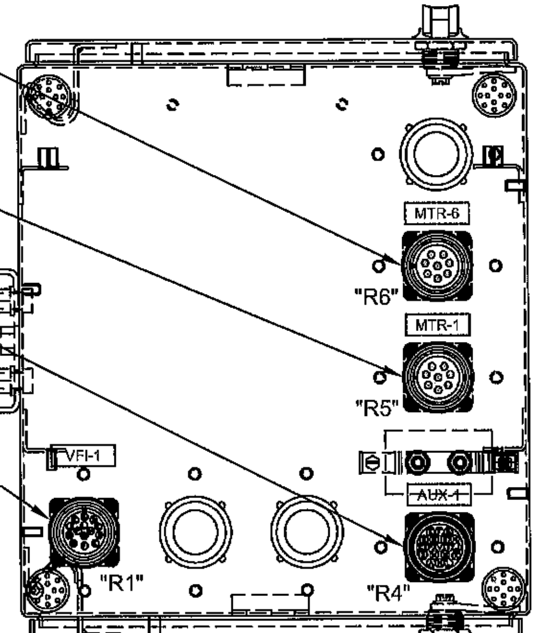


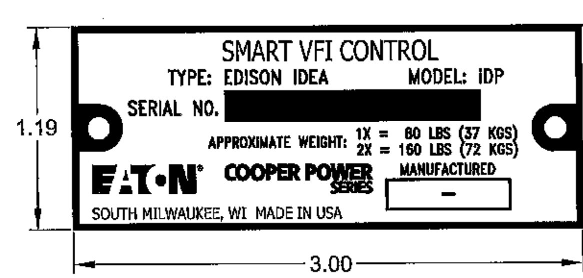
RIGHT SIDE VIEW

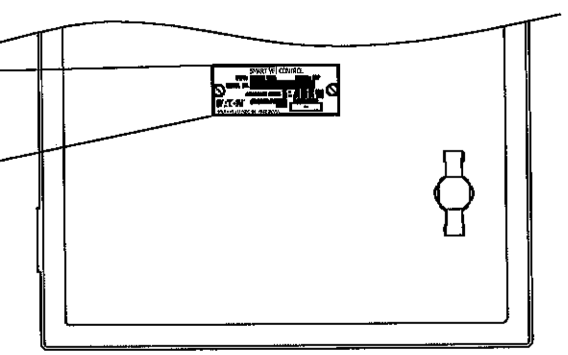


BACK VIEW WITHOUT DOOR









FRONT DOOR (REF)

SEE SHEET 2 FOR DETAIL VIEW OF FRONT AND BACK PANELS

KIDP00006, IDP-210 IDEA+ EXP RELAY CONTROL
DIRECT MOTOR AUTOMATION: 1 VFI, 1 RVAC
1 AMP CT INPUTS (4), 67/120 PT INPUTS (6)
SOFTWARE HOTLINE TAG, CLOSE INHIBIT, NO LAMP
IN SINGLE SIZE, 2 DOOR, MILD STEEL CABINET

REV	DATE	BY	STATUS
01	09-15-16	STL	RELEASED
CHECKED BY: STL			DATE:09-15-16

CUST. ORD. NO.	SHOP ORD. NO.
5501419952	209625385

CUSTOMER: BORDER STATES ELECTRIC SUPPLY

REFERENCE DRAWINGS:
REFERENCE K1602810B1, IDP-210 OUTLINE DRAWING W/ACCESSORIES
REFERENCE K1602810C1, IDP-210 SCHEMATIC DIAGRAM W/ACCESSORIES

MATERIAL: KIDP00006

ALL DIMENSIONS ARE IN INCHES [MM]

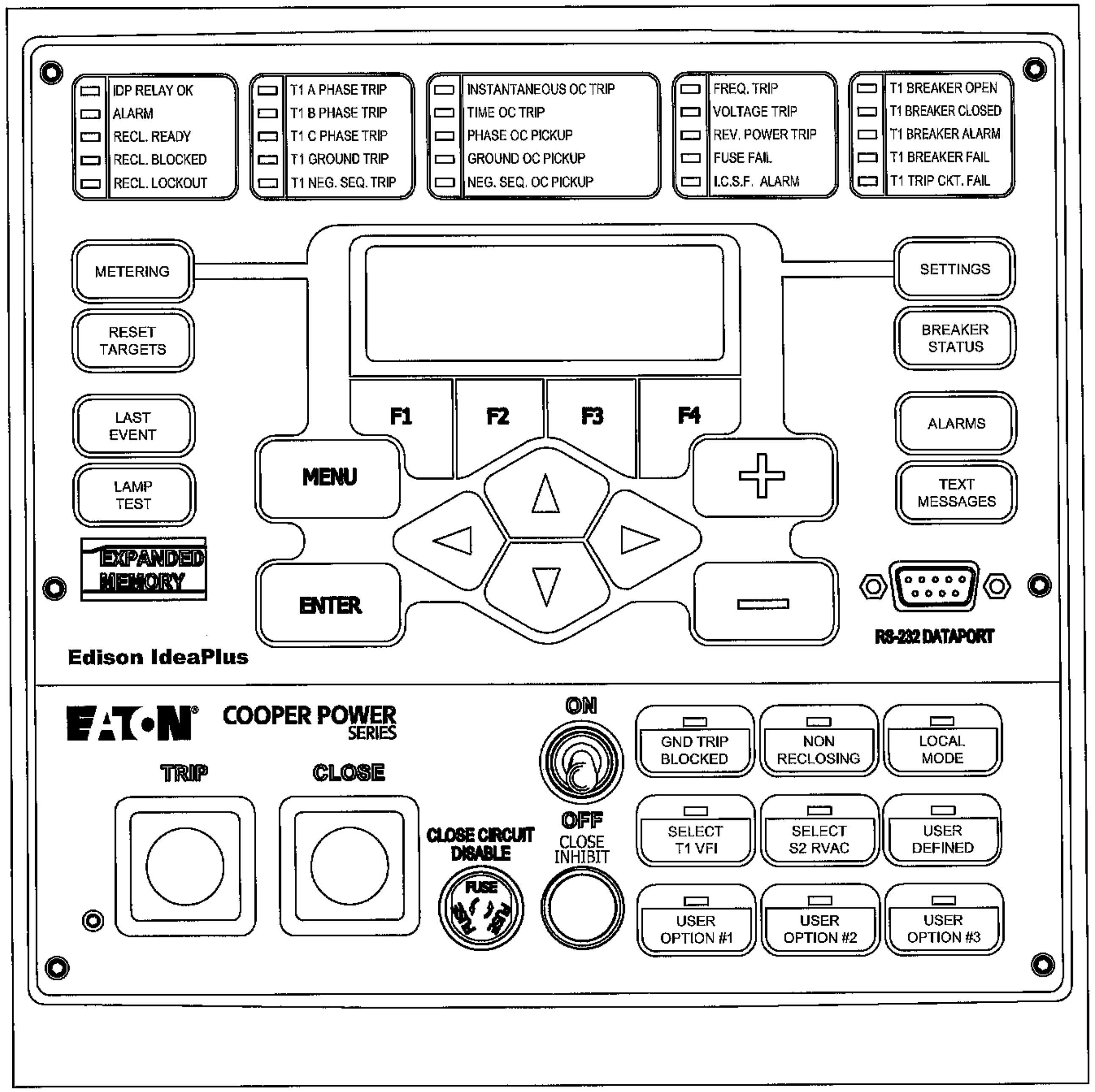
EATON Powering Business Worldwide

TITLE: CTRL OUTL, IDEA+ RELAY, KIDP-A-E210A6CEN

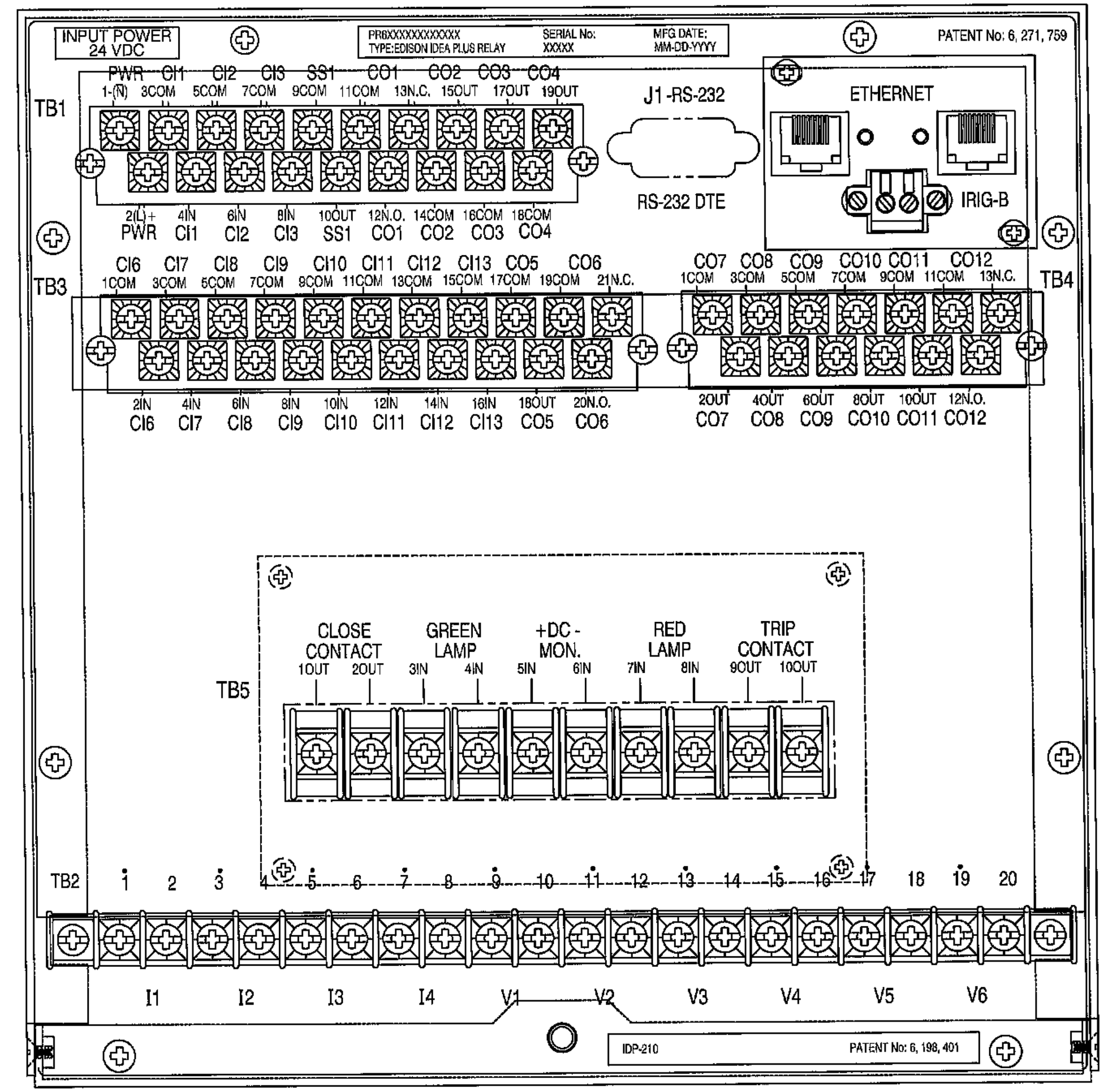
DESC: COOPER POWER SERIES CTRL OUTLINE, IDP-210 IDEA+ RELAY, KIDP00006, KIDP-A-E210A6CEN, VFI1, SW2

DWG:	DATE:	REF:	SHEET #:	SCALE:	REV:
PKE	08-05-16	DATA003552	1 of 2	NTS	01

K1602810B1



FRONT PANEL (SCALE: NTS)



BACK PANEL (SCALE: NTS)

REV	DATE	BY	STATUS
01	09-15-16	STL	RELEASED

CHECKED BY: STL | DATE: 09-15-16

CUST. ORD. NO.	SHOP ORD. NO.
5501419952	209625385

CUSTOMER: BORDER STATES ELECTRIC SUPPLY

REFERENCE DRAWINGS:
REFERENCE K1602810B1, IDP-210 OUTLINE DRAWING W/ACCESSORIES
REFERENCE K1602810C1, IDP-210 SCHEMATIC DIAGRAM W/ACCESSORIES

MATERIAL: KIDP00006

ALL DIMENSIONS ARE IN INCHES [MM]

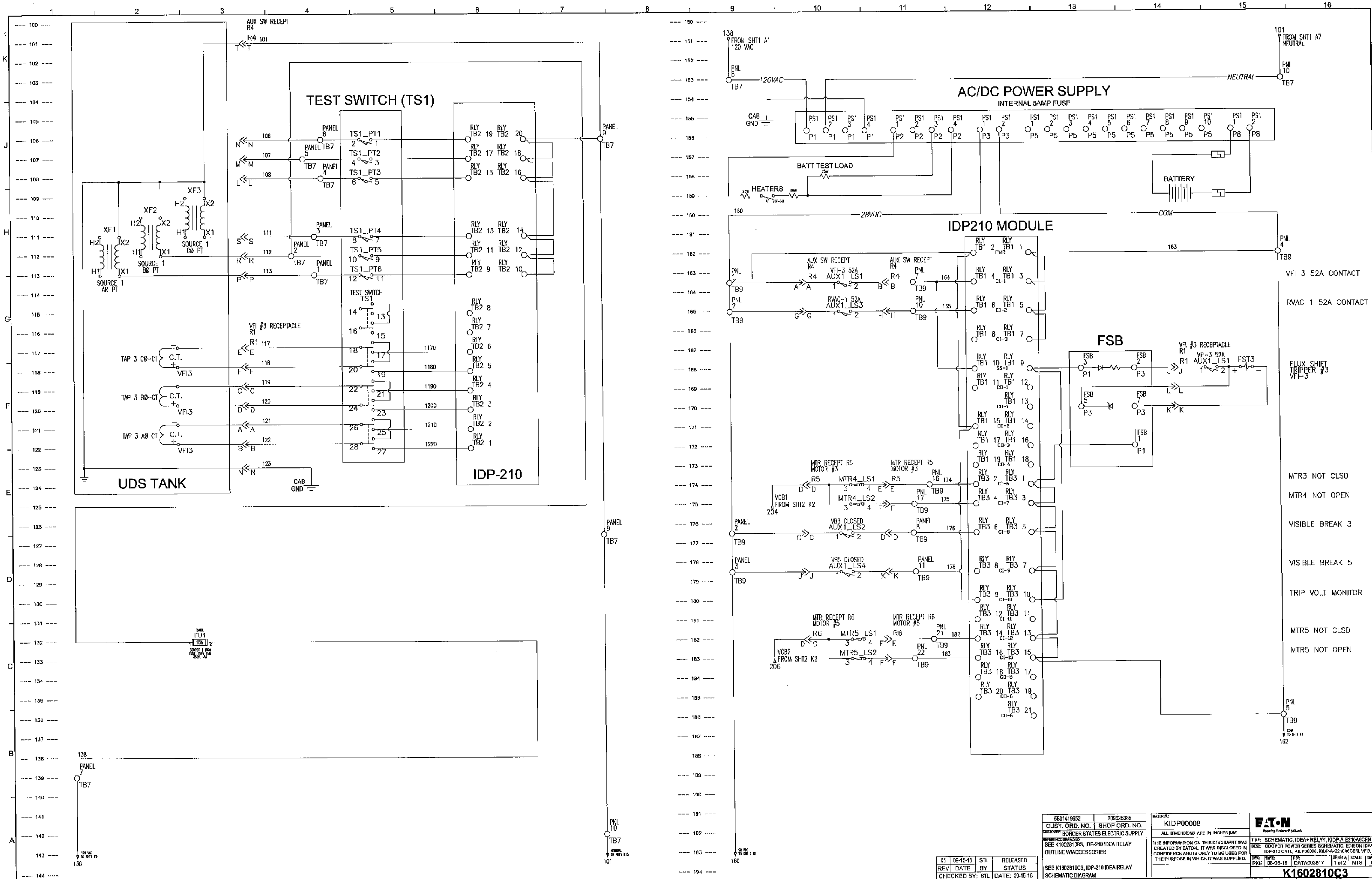
EATON Powering Business Worldwide

TITLE: CTRL OUTL, IDEA+ RELAY, KIDP-A-E210A6CEN

DESC: COOPER POWER SERIES CTRL OUTLINE, IDP-210 IDEA+ RELAY, KIDP00006, KIDP-A-E210A6CEN, VFI1, SW2

DWG:	DATE:	REF:	SHEET #:	SCALE:	REV:
PKE	08-05-16	DATA003552	2 of 2	NTS	01

K1602810B1


TEST SWITCH (TS1)
UDS TANK
IDP-210
AC/DC POWER SUPPLY
INTERNAL 5AMP FUSE
IDP210 MODULE
FSB
BATT TEST LOAD
HEATERS
BATTERY
120VAC
NEUTRAL
28VDC
COM
138 FROM SHT1 A1 120 VAC
101 FROM SHT1 A7 NEUTRAL
SOURCE 1 AØ PT
SOURCE 1 BØ PT
SOURCE 1 CØ PT
TAP 3 CØ-CT
TAP 3 BØ-CT
TAP 3 AØ CT
VFI #3 RECEPTACLE
AUX SW RECEPT
VFI 3 52A CONTACT
RVAC 1 52A CONTACT
FLUX SHIFT TRIPPER #3 VFI-3
MTR3 NOT CLSD
MTR4 NOT OPEN
VISIBLE BREAK 3
VISIBLE BREAK 5
TRIP VOLT MONITOR
MTR5 NOT CLSD
MTR5 NOT OPEN
VCB1 FROM SHT2 K2
VCB2 FROM SHT2 K2
5501419952
209626385
CUST. ORD. NO.
SHOP ORD. NO.
BORDER STATES ELECTRIC SUPPLY
SEE K1602810B3, IDP-210 IDEA RELAY OUTLINE W/ACCESSORIES
SEE K1602810C3, IDP-210 IDEA RELAY SCHEMATIC DIAGRAM
01 09-15-16 STL RELEASED
REV DATE BY STATUS
CHECKED BY: STL DATE: 09-15-16
KIDP00008
ALL DIMENSIONS ARE IN INCHES [MM]
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SCHEMATIC, IDEA+ RELAY, KIDP-A-E210A5CEM
COOPER POWER SERIES SCHEMATIC, EDISON IDEA+ IDP-210 CNTL, KIDP00206, KIDP-A-E210A5CEM, VFG.
PKE 08-05-16 DATA003517 1 of 2 NTS 01
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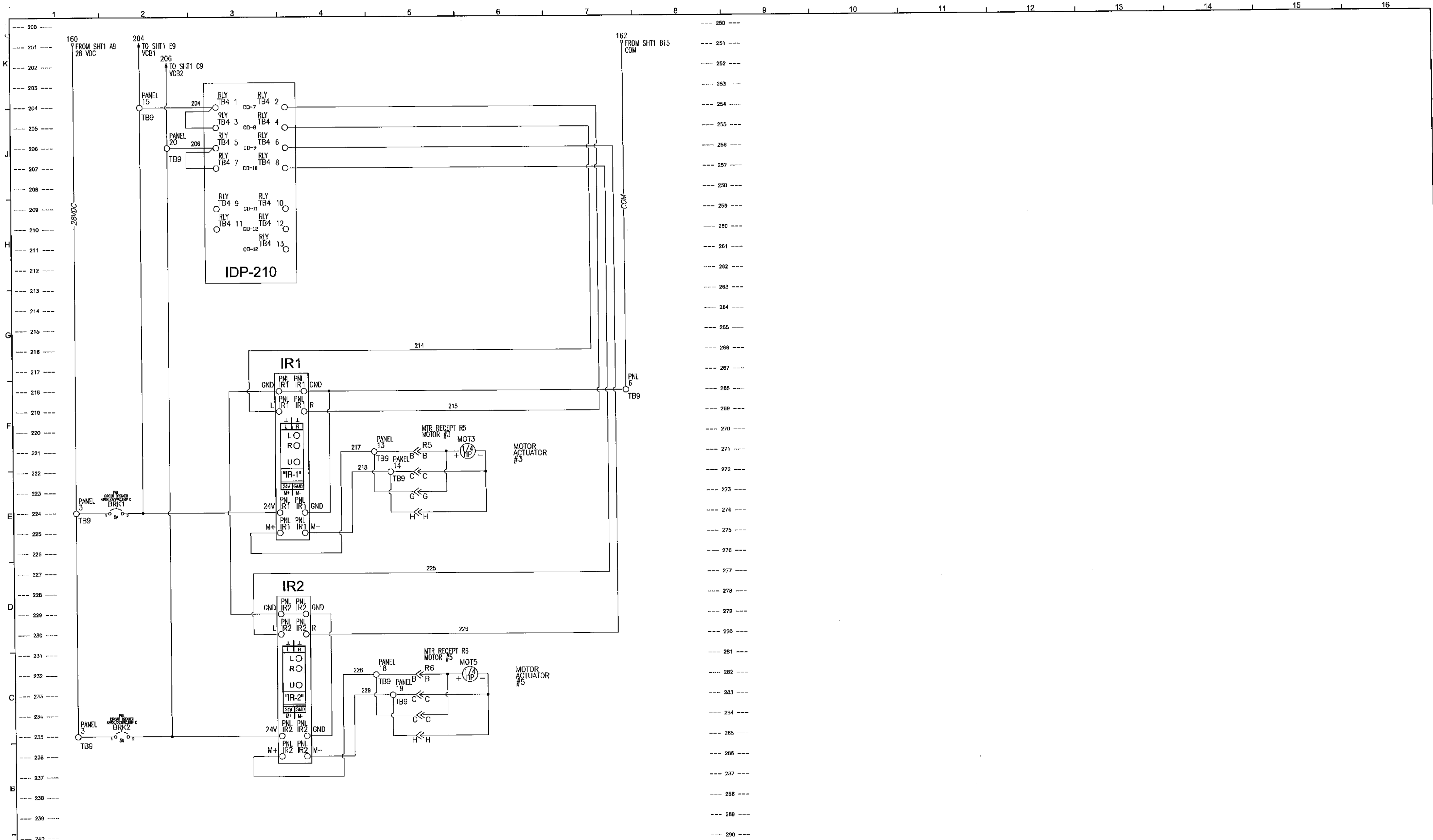

01	09-15-16	STL	RELEASED
REV	DATE	BY	STATUS
CHECKED BY: STL			DATE: 09-15-16

5501419952	209825385
CUST. ORD. NO.	SHOP ORD. NO.

CUSTOMER: BORDER STATES ELECTRIC SUPPLY

REFERENCE DRAWINGS:
SEE K1602810B3, IDP-210 IDEA RELAY OUTLINE W/ACCESSORIES
SEE K1602810C3, IDP-210 IDEA RELAY SCHEMATIC DIAGRAM

MATERIAL: KIDP00008

ALL DIMENSIONS ARE IN INCHES [MM]

EATON Powering Business Worldwide

TITLE: SCHEMATIC, IDEA+ RELAY, KIDP-A-E210A6CEN

DESC: COOPER POWER SERIES SCHEMATIC, EDISON IDEA+ IDP-210 CNTL, KIDP00008, KIDP-A-E210A6CEN, VFB,

DWG:	DATE:	REF:	SHEET #:	SCALE:	REV:
PKE	08-05-16	DATA003517	2 of 2	NTS	01

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Appendix H – Northwestern Energy Interconnection Guidelines

Technical Guidelines for Small Generation Interconnections to NWE's Electric Distribution System

July 2016

Version 1.5

Table of Contents

1.0 Purpose

The purpose of this guide is to outline the technical requirements for connecting a Distributed Energy Resource (DER) Small Generation Facility to the Electric Distribution Company's (EDC) system. This guide covers Small Generation Facilities located on the Customer's premises that have an aggregate nameplate capacity that is less than or equal to 10 MW, is designed to operate in parallel with the Electric Distribution System (EDS) and NOT as a standalone island or microgrid. This guide is intended to be consistent with the requirements of the current version of IEEE Standard 1547, "Standard for Interconnecting Distributed Resources with Electric Power Systems", NWE Electric Service Requirements and Guidelines, as well as Federal, State and Local regulations, and accepted industry practices and standards.

2.0 Definitions

- **Anti-Islanding:** Detection capability required by the current version of IEEE 1547 for grid-tied generators on the DER that senses when a power outage has occurred on the utility lines and shuts itself off to minimize the possibility of back feeding into the utility system.
- **DER Customer**: Any entity connected to the utility system for the purpose of interconnecting a DER onto the EDS.
- **Direct Transfer Trip (DTT):** The rapid separation of all sources of generation at a Customer's location initiated upon the operation of an automatic upstream protection device (substation breaker or line recloser) by means of a dedicated communication channel between the upstream device and the DER.
- **Distributed Energy Resource (DER):** Electric power generation facilities connected to an EDS through a POI.
- **Electric Distribution Company (EDC):** An electric utility that distributes electricity to end users within Montana and is subject to regulation by the Montana Public Service Commission (MPSC).
- **Electric Distribution System (EDS):** Facilities and equipment constructed and maintained by the EDC used to transmit electricity to ultimate usage points such as homes and commercial areas. This electrical infrastructure is subject to regulation by the MPSC.

- **Flicker:** A variation of input voltage sufficient in duration to allow visual observation of a change in electric light source intensity. Flicker increases with the magnitude of fluctuation. The EDC refers to the current version of IEEE 1453 as the industry acceptable standard addressing flicker requirements.

- **Generator Step Up Transformer (GSU):** The interconnection transformer at the generation site used to step up the generation voltage to the utility EDS voltage.

- **Point of Interconnection (POI):** The place where change of control and usually ownership of equipment occurs between an EDC and a Customer, normally at the generator side terminals of the EDC meter.

3.0 Technical Requirements

3.1 Safety Considerations

1. The connection of the DER facility to the EDS must not compromise the safety of EDC's customers, company personnel, or the Customer. The Customer is responsible for providing adequate protection to EDC facilities for conditions arising from the operation of generation under all EDS operating conditions.
2. The minimum protection requirements are designed and intended to protect the EDS only. The Customer shall provide at their sole expense, all devices necessary to protect the DER from conditions that may occur on the EDS resulting in interruptions and restorations of electrical service. The installed equipment should protect the DER from over voltage, under voltage, overload, short circuits including ground fault conditions, open circuits, phase unbalance and reversal, over and under frequency conditions and other injurious electrical conditions that may arise during the operation of the EDS.

3.2 EDS Power Quality

1. Steady State Voltage
   a. Customer owned equipment will not cause the EDS voltage to go outside of the limits set by the current versions of ANSI C84.1 and IEEE 1547. If high or low voltage results from

the non-compliant operation of the DER as determined by the EDC, it shall be disconnected until the problem is resolved.

2. Voltage Flicker
    a. In accordance with the current version of IEEE 1453, flicker shall not exceed a 3.0% voltage change, measured at the POI. If non-compliant voltage flicker results from the operation of the DER as determined by the EDC, it shall be disconnected until the problem is resolved.
    b. A critical time for rapid voltage rise occurs when reconnecting the DER to the EDS. This voltage swing could occur rapidly and may violate EDC guidelines for voltage flicker. If so, then the DER will be required to stagger and appropriately ramp generation as necessary to maintain voltage flicker under 3%.
3. Harmonics
    a. The Small Generation Facility shall not cause voltage or current harmonic content or total harmonic distortion (THD) in excess of the limits of the current versions of IEEE 519 and 1547 when measured at the POI.
4. Temporary and Transient Overvoltages
    a. Ground Fault Overvoltage – GFO occurs when an ungrounded voltage source feeds a four-wire feeder containing a single-phase to ground fault. The result is a phase-to-ground overvoltage on the unfaulted phases. The EDC primarily operates the EDS with a four wire effectively grounded system. The effectively grounded system together with an appropriate wye-grounded utility side transformer mitigates GFO damages on the area EDS. Additional considerations will need to be considered on sections of the EDS that are not four wire effectively grounded systems. The DER must not be a source of objectionable overvoltages.
    b. Load Rejection Overvoltage - LRO can occur when a distribution feeder containing a large amount of generation with a smaller amount of load becomes disconnected from the grid. The result is a high generation to load ratio that can create an overvoltage until the generators detect the overvoltage condition and disconnect from the area EDS. A transient overvoltage can occur when the current output from that DER is temporarily fed into the local load. Many distribution feeders on the EDS have low minimum daytime loading. These low loading conditions may be significantly less than the generation level. The Customer will design and operate their system so as not to create or contribute to damaging overvoltages to loads and equipment on the EDS.
5. Anti-Islanding
    a. Localized areas of utility load including DER can become separated from the utility source. This is normally a very undesirable condition, as left unchecked, the DER could

potentially serve EDS load without EDC control of voltage or frequency and without properly designed system protection. This could leave a utility line energized by the DER when utility workers expect the line to be dead. When utility load exceeds the capacity of the DER, the generator should trip on under voltage, over current, or abnormal frequency according to the current version of IEEE 1547 and separate from the utility. Where load and generation are closely matched, other "anti-islanding" provisions will be required.

   b. EDC requires UL1741 certified inverters for utility scale DER projects. The UL1741 certification shows compliance with anti-islanding capabilities for use on distribution feeders. The potential for islanding may increase with the addition of utility scale inverter based generators or any synchronous generation. EDC may require DTT as discussed below in section 3.3.5.

6. Power Factor
   a. The Customer shall correct any power factor deviations that may occur as a result of operating the DER. Unless otherwise agreed to in writing with the EDC, the DER operating power factor shall be corrected at the metering POI to 100%

7. Continuous Compliant Operation
   a. The Customer will be required to demonstrate compliance to the current version of IEEE 1547 standard during commissioning or periodic testing of the DER. Failure to comply with the performance requirements of the current version of IEEE 1547 at any time will constitute grounds to prohibit the DER from initial interconnection or from continuing to operate on the EDS.

3.3 Distribution System Equipment

1. Substation Equipment (where applicable)
   a. Substation equipment will be reviewed for compatibility with the proposed generation project. Reverse power flow through the substation may be considered.
   b. Reverse power flow will require upgrades to older regulator controllers or Load Tap Changer controls. Communication and control wires will be included in the upgrades.
   c. Feeder breakers and electronic reclosers with older relays may require an upgraded relay compatible with current relaying and communication standards.
   d. Feeders that are utilizing a hydraulic recloser for a feeder breaker may be upgraded to an electronic recloser for the feeder breaker.

2. Substation Relay & Protection (where applicable)
    a. A need for DTT may require relay and communication hardware upgrades.
3. Distribution Circuits and System Protection (where applicable)
    a. The distribution circuit conductors from the substation to the DER must be of sufficient size to accommodate both the maximum expected loading, and to prevent excessive steady state voltage drop and voltage rise.
    b. Existing line reclosers, regulators, and capacitor banks will be evaluated for compatibility with the DER project. Line regulators may require a controller upgrade for reverse power flow conditions. Capacitor banks may require a relocation. Fixed capacitor banks may need a conversion to a switched bank, allowing for coordination with the generator. Line reclosers and other protective devices may be required to be installed or relocated to preserve circuit coordination.
    c. For any DER that can export 0.5 MW of power or greater onto the EDS, the EDC reserves the right to install an automated switch at the POI for EDS stability and control.
4. Metering and Communications
    a. The EDC will install metering at the POI. All Small Generation Facilities above 1MW in size will require metering quantities to be brought into the EDC Grid Control Center via SCADA.
5. Transfer Trip Schemes (where applicable)
    a. A Transfer Trip scheme will normally be comprised of a relay located at the EDS substation feeder breaker which communicates via radio or fiber optic cable with the EDC's electronic recloser at the POI. Whenever the EDS substation breaker opens, a trip signal is sent to the EDC owned electronic recloser at the DER site to automatically trip the generation off line.
    b. The DER system will not be permitted to energize a de-energized EDC circuit; therefore, anti-islanding protection is required for Small Generation Facilities on the EDS. If the EDC determines that an active communication based anti-islanding protection scheme is required to mitigate the risk of a formation of an island, in addition to the Small Generation Facilities own anti-islanding control scheme, then use of direct transfer trip (DTT) is a definitive protection means for anti-islanding protection. The EDC reserves the right, even at a later date, to require a DTT installation at the Customer's expense for any project if operational experience or additional DER projects result in the need for enhanced anti-islanding protection on the EDS. Multiple generators feeding a distribution circuit will increase the probability of failed anti-islanding detection and may necessitate the need for a transfer trip scheme for these additional projects unless a detailed dynamic anti-islanding study concludes that the additional generation does not increase the risk of islanding.

3.4 DER Customer Interconnection Equipment

1. Non-Exporting Generators (where applicable)
    a. A non-exporting DER is one designed to ensure power does not export back onto the EDS. All electric energy generated by non-exporting DER is consumed by the Customer. Customer stand-by generators also fall into this category.
    b. The non-exporting DER will use reverse power relays or other protection functions that prevent power flow onto the EDS
2. Generator Step Up Transformer (GSU) – (where applicable)
    a. The Customer supplied GSU is an important link between the low voltage DER equipment and the medium voltage EDS. The GSU connection needs to be compatible with the EDS construction and grounding requirements. Where the DER is served from a four-wire distribution circuit with a multi-grounded neutral, an effectively grounded system with respect to the EDS must be maintained to ensure neutral stability and avoid distribution circuit over voltage during isolation of the area EDS. Therefore the GSU utility side connection will need to be wye grounded unless specifically instructed otherwise. The EDC requires the Customer to select the transformer's DER side winding configurations so that the DER does not produce damaging overvoltages on the EDS.
    b. EDC will accept the following transformer winding configurations on four wire grounded wye feeders:
        - A wye-grounded utility side to wye-grounded customer side transformer with an effectively grounded utility source.
        - A wye-grounded utility side to wye un-grounded customer side transformer with an effectively grounded utility source.
    c. Any distribution feeder not constructed four wire grounded wye will need to have the interconnection evaluated for the appropriate transformer connection.
3. Inverters (where applicable)
    a. Inverters shall be certified to UL 1741 and be compliant to the current version of IEEE 1547. They must also be on the approved list published by the California Energy Commission (CEC).
    b. If photovoltaic units are used, they must be compliant to the current version of IEEE 929.
4. Governing Authority
    a. The DER shall be installed in conformance with all applicable requirements of the National Electric Code and local building or electrical codes.

b. The DER must be inspected and approved by the appropriate state or city electrical inspector and this agreement must be fully executed and returned to the EDC before parallel operation can begin. It is up to the Customer to notify the EDC that the inspection has been completed and approved.

5. Control Set Points

   a. The Customer or Customer's agents shall not alter the agreed upon control set points without first notifying EDC in writing of the Customer's intent to make any such modifications. The set point changes must be agreed upon in writing by the EDC before changes can be implemented.

6. Disconnect Access

The DER shall be capable of being manually isolated from the EDS by means of an external, visible load break disconnect switch, electrically located at the POI. The disconnect switch should be located within 10 feet of the Customer's electric meter and shall be clearly marked "Generator Disconnect Switch" on a weather resistant placard. This switch shall be readily accessible to the EDC at all times, and the EDC shall have the right to lock this switch open whenever necessary to maintain safe electrical operating conditions on the EDS. If the disconnect switch is located farther than 10 feet away from the POI, the location must be approved in writing by the EDC and a weather resistant placard shall be mounted next to the meter indicating clearly where the disconnect switch is located.

Appendix I – Northwestern Energy Testing Requirements

NorthWestern Energy Interconnection Test Specifications And Performance Requirements For Generation Interconnected to Distribution Systems

Summary

This document contains an itemized list of the test specifications and performance requirements required to approve the interconnection of a Distributed Resource (DR) to the NorthWestern Energy's distribution systems. DR interconnection test specifications and performance requirements are based on the IEEE standard 1547-2003. NorthWestern Energy's interconnection requirements may be more stringent than IEEE 1547-2003. This document is intended to supplement IEEE 1547-2003, and not to replace it.

The following sections identify the test and performance requirements necessary to demonstrate that the interconnection of a Distributed Resource shall meet the requirements as outlined in Clause 5 of IEEE 1547-2003. These tests are required for all interconnection systems. The results of these tests shall be formally documented.

- Section 1: Pre-Parallel Inspection
- Section 2: Commissioning Test Checklist & Certification
- Section 3: Design Tests
- Section 4: Interconnection Installation Evaluation
- Section 5: Commissioning Tests

Section 1: Pre-Parallel Inspection

Name of Project:___________________________________
Location:____

1. Maintenance Data:

    Generation Customers Maintenance Chief:____________________________
    Telephone Number:____
    Regular Maintenance Interval:_______________________________________
    Electrical Contractor:____

    Maximum Operational Output Allowed:_______________________________
    Minimum Operational Output Allowed:_______________________________

2. Test Reports Attached? ___Yes ___No
    If not, who has test reports:____

3. Generation Facility Manual Disconnect Device for NorthWestern Energy Line Clearances:

    Manufacturer:____
    Model Number:____
    NorthWestern Energy Device Number:_________________________________

4. Designated NorthWestern Energy Control Center:________________________

5. NorthWestern Energy Inspector:______________________________________
    Name Phone No

Date Inspection Performed:_____________________________________
Date Facility Placed on 30 day Test Released:______________________

1a. Generator Nameplate:
____________KW __________Volts ______pf
____________1Phs __________3Phs

b. Generator Type: Synchronizing: Connection:
____Synchronous ____Auto ____WYE-Grounded
____Induction ____ ____WYE-Ungrounded
____DC w/ Inverter ____Delta

Manufacturer:________________________ Serial Number:________________________

Generator Prime Mover:
____Wind ____Water ____Steam ____Solar ____Fuel Cell
____Bio-Mass ____Other, Specify________________________

Generator Breaker
Manufacturer:________________________ Serial Number:________________________

__________DC Shunt Trip (if fault direction is required) w/ Battery
__________Control Voltage (AC Holding Coil)
__________Others

Dedicated Transformer: ____Yes ____3Phs ____1Phs ____3-1Phs
____No ____Bank of 3 1Phs

Transformer Owner (NorthWestern Energy or Customer):_________________________

Bank Rating:______ KVA Transformer:______ %______MVA Base

Transformer Connection: __________Primary Volts
__________Secondary Volts

Protected By: __________ Fuse Size __________Relay Settings

Ground Protection Required?: ____Yes ____No

If Yes, Type of Ground Detection:
___Ground Bank w/ Overcurrent Relay
___Broken Delta Ground Bank w/ low pickup overvoltage relay
___Ground Overcurrent Relay in Neutral or dedicated transformer
___Low Voltage pickup in Overvoltage relay in elevated neutral of dedicated transformer
___Other, Explain:____________________

NorthWestern Energy Pre-Parallel Inspection Checklist

The Customer must submit this Pre-Parallel Inspection (PPI) Checklist To NorthWestern Energy at least 3-weeks prior to requesting a PPI date. This checklist is to evaluate customer preparedness for the PPI.

- ❑ Single Line Drawings, including the following
  - ❑ NorthWestern Energy Interconnection Facilities (Switches, Meters, Transformers, etc.)
  - ❑ Customer Operating Voltages, capacities, and loads
  - ❑ Customers Secondary Switchboard
  - ❑ Customers Electric Revenue Meter
  - ❑ Customers Main, Load, and Generator Circuit Breakers
  - ❑ Customers Step-up Transformers (Nameplate information, i.e., voltages, capacities, winding arrangements, connections, impedances, etc.)
  - ❑ Customers Net Gen Electric Output Meter Panel For NorthWestern Energy Meter. Including Manufacturers Panel Specification Sheets.
  - ❑ Customers Disconnect Switch for NorthWestern Energy's use. Including Manufacturers Switch Specification Sheets.
  - ❑ Customer Protective Relays and Settings.
  - ❑ Customers Generator(s) and the Generator(s) auxiliary loads.

- ❑ Site Drawing (Show NorthWestern Energy's Service and customer's electrical generator components)

- ❑ Protective Diagrams, elementary or three line drawings (as required)

- ❑ Description of Protective Scheme Function (as required)

- ❑ Complete and Accurate Information In NorthWestern Energy's Pre-Parallel Inspection Sheet.

- ❑ All Relay Bench Test Reports

- ❑ All Other Test Reports (CT and PT Transformer Test Reports, and CT and PT Control Wire resistance Test Reports).

- ❑ Protection and Control Equipment Certification

- ❑ Copies of all Pertinent Letters that affect control and protection as agreed to by NorthWestern Energy.

Section 2:
Commissioning Test Checklist & Certification

Basic Requirements

Commissioning testing shall be performed on-site prior to parallel operation of a generating facility with NorthWestern Energy. Commissioning testing shall also be performed on-site any time hardware or software is changed that may impact connection requirements.

Commissioning testing shall be performed by personnel qualified in the use of appropriate testing protective equipment such as a professional engineer, factory-certified technician, or a licensed electrician with experience in testing protective equipment. Commissioning testing should be performed in accordance with manufacturer's recommended test procedures.

Commissioning testing shall be completed and certified prior to pre-parallel inspection (PPI) being performed by NorthWestern Energy

NorthWestern Energy shall witness commissioning tests as described below or to require written certification by the installer describing which tests were performed and their results. Protective functions to be tested during commissioning, particularly with respect to non-certified equipment, may consist of the following:

Function Tests:

- ☐ Over and Under Voltage
- ☐ Over and Under Frequency
- ☐ Anti-Islanding Function
- ☐ Non-Export Function
- ☐ Inability to energize dead line
- ☐ Time delay on restart after NorthWestern Energy source is stable
- ☐ Utility system fault detection
- ☐ Synchronizing Controls
- ☐ Other Protective Functions per the Interconnection Agreement.

Additional Testing:

- ☐ Verify final protective function settings
- ☐ Trip test
- ☐ In-service test

Protective function settings that have been changed after factory testing will require field verification. Tests shall be performed using injected secondary frequencies, voltages and currents, applied waveforms, a test connection using a generator to simulate abnormal utility voltage/frequency, or varying the set points to show that the device trips at the measured (actual) utility voltage and frequency.

The Non-Islanding function shall be checked by operating a load break disconnect switch to verify the interconnection equipment ceases to energize NorthWestern Energy's distribution system and does not re-energize it for the required time delay after the switch is closed.

The Non-Exporting function shall be checked using secondary injection techniques. This function may also be tested by adjusting the generating facility output and local loads to verify that the applicable non-exporting criteria (i.e., reverse power or under power) are met.

A supplemental review or an interconnection study may impose additional components or additional testing.

Non-Certified Equipment:

Non-certified equipment shall be subjected to the standard certified equipment commissioning tests as well as additional appropriate tests. With NorthWestern Energy's approval, some of these tests may be performed in the factory, in the field as part of commissioning, or a combination of both. NorthWestern Energy may also approve a reduced set of tests for a particular application at its discretion, for example, if it determines that it has sufficient experience with the equipment.

Verification of Settings:

If testing is part of the commissioning process, then, at the completion of such testing, the producer shall confirm all devices are set to NorthWestern Energy approved settings. This step shall be documented in the commissioning test certification and during the onsite pre-parallel inspection (PPI) .

Trip Tests:

Interconnection protective functions and devices (e.g., reverse power relays) that have not previously been tested as part of the interconnection facilities with their associated interrupting devices (e.g., contactor or circuit breaker) shall be trip tested during commissioning and during the onsite pre-parallel inspection (PPI). The trip test shall be adequate to prove that the associated interrupting devices open when the protective devices operate. Interlocking circuits between protective function devices or between interrupting devices shall be similarly tested unless they are part of a system that has been tested and approved during manufacture.

In –Service Tests:

Interconnection protective functions and devices that have not previously been tested as part of the interconnection facilities with their associated instrument transformers or that are wired in the field shall be given an in-service test during commissioning. This test will verify proper wiring, polarity, CT/PT ratios, and proper operation of the measuring circuits. The in-service test shall be made with the power system energized and carrying a known level of current. A measurement shall be made of the magnitude and phase angle of each alternating current voltage and current connected to the protective device and the results compared to expected values. For protective devise with built-in metering functions that report current and voltage magnitudes and phase angles, or magnitudes of current, voltage, and real and reactive power, the metered values may be used for in-service testing. Otherwise, portable ammeters, voltmeters, and phase-angle meters shall be used.

Section 3: Design Tests and Performance Requirements

Test #1 Response to abnormal voltage and frequency. IEEE 1547-2003 Clause 5.1.1

The Distributed Resource (DR) shall demonstrate the ability to cease energization of the distribution system when the voltage or frequency exceeds the limits as specified in 4.2.3 and 4.2.4 of IEEE 1547-2003. The DR shall be tested at the minimum, midpoint, and maximum of field adjustable set points. These tests shall be conducted using either simulated utility or secondary injection method.

Voltage Requirements per IEEE 1547-2003 Clause 4.1.1 & 4.2.3
The protection functions of the interconnection system shall detect the effective (rms) value of each phase-to-phase voltage. The DR shall not cause the service voltage on the distribution system to go outside ±4% of base voltage (120 volts) at the point of common coupling. Accordingly, when any voltage is outside this parameter, the DR shall cease to energize the distribution system within a clearing time of 10 cycles. Clearing time is the time between the start of the abnormal condition and when the DR ceases to energize the distribution system. Voltage set points shall be field adjustable.

Frequency Requirements per IEEE 1547-2003 Clause 4.2.4
When the system frequency is greater than +/- 0.5Hz of 60.0Hz, the DR shall demonstrate ability to cease to energize the distribution system within 10 cycles. Clearing time is the time between the start of the abnormal condition and when the DR ceases to energize the distribution system. Frequency set points shall be field adjustable.

Test #2 Synchronization. IEEE 1547-2003 Clause 5.1.2

This test shall demonstrate that at the moment of the paralleling-device closure, all three parameters in table 3 are within the stated ranges. This test shall also demonstrate that if any of the parameters are outside of the ranges stated in the table, the paralleling-device shall not close.

Table 3 – Synchronization parameter limits for synchronous interconnection.

Aggregate rating of DR Units (kVA)	Frequency difference (Δf, Hz)	Voltage difference (ΔV, %)	Phase angle difference (ΔΦ, °)
> 0– 10,000	0.1	3	10

Flicker Requirements per IEEE 1547-2003 Clause 4.3.2

The DR shall not create objectionable flicker for other customers on the NorthWestern Energy distribution system. Flicker is considered objectionable when the voltage fluctuates more than 5%, or it causes equipment misoperation.

Test #3 Interconnect Integrity Test. IEEE 1547-2003 Clause 5.1.3

With NorthWestern Energy's approval, some of these tests may be performed in the factory by the manufacturer, in the field as part of commissioning, or a combination of both. NorthWestern Energy may also approve a reduced set of tests for a particular application at its discretion, for example, if it determines that it has sufficient experience with the equipment.

EMI Protection IEEE 1547-2003 Clause 5.1.3.1
The interconnection system shall be tested in accordance with IEEE Std C37.90.2-1995 to confirm that the results are in compliance with 4.1.8.1. The influence of electromagnetic interference (EMI) shall not result in a change in state or misoperation of the interconnection system.

Surge Withstand Performance IEEE 1547-2003 Clause 5.1.3.2
The interconnection system shall be tested for the requirement in 4.1.8.2 in all normal operating modes in accordance with IEEE Std C62.45-2002 for equipment rated less than 1,000 V to confirm that the surge withstand capability is met by using the selected test level(s) from IEEE Std C62.41.2-2002. Interconnection system equipment rated greater than 1000 V shall be tested in accordance with manufacturer or system integrator designated applicable standards. For interconnection system equipment signal and control circuits, use IEEE Std C37.90.1-2002. The results of these tests shall indicate that the unit did not fail, did not misoperate, and did not provide misinformation.

Paralleling Device IEEE 1547-2003 Clause 5.1.3.3
A dielectric test across the open-circuited paralleling device shall be conducted to confirm compliance with the requirements of 4.1.8.3 that the interconnection system paralleling-device shall be capable of withstanding 220% of the interconnection system rated voltage.

Test #4 Unintentional Islanding. IEEE 1547-2003 Clause 5.1.4

Unintentional Islanding IEEE 1547-2003 Clause 4.4.1
For an unintentional island in which the DR energizes a portion of NorthWestern Energy's distribution system, the DR shall detect the island and cease to energize the distribution system within 10 cycles of the formation of an island.

Test #5 Power Factor and Harmonics

Power Factor Requirements per NWE
The Interconnection Customer shall design its Small Qualifying Facility to maintain a composite power delivery at continuous rated power output measured at the generator terminals at a power factor within the range of 0.90 leading to 0.95 lagging, unless the Transmission Provider has established different requirements that apply to all similarly situated generators in the control area on a comparable basis

Limitation of DC Injection. IEEE 1547-2003 Clause 5.1.6
The intent of the harmonics interconnection test is to assess that under a controlled set of conditions the DR meets the harmonic limits specified in 4.3.3.

The DR shall be operated at an output test load current, I_L, of 33%, 66%, and at a level as close to 100% of rated output current as practical. Total harmonics shall not exceed the levels in table 4. Voltage harmonics shall be measured line to line for 3-phase/3-wire systems, and line to neutral for 3-phase/4-wire systems.

Table 4 – Maximum harmonic current and voltage distortion in percent of current (I)[a]

Individual Harmonic Order h (odd Harmonics)[b]	**h < 11**	**11 ≤ h ≤ 17**	**17 ≤ h ≤ 23**	**23 ≤ h < 35**	**35 ≤ h**	**Total Demand Distortion (TDD)**
Percent (%)	4.0	2.0	1.5	0.6	0.3	5.0

[a]I = the greater of the NorthWestern Energy maximum load current integrated demand (15 or 30 minutes) without the DR, or the DR rated current capacity (transformed to the point of common coupling).
[b]Even harmonics are limited to 25% of the odd harmonic limits above.

Design Test Check List

- **Test #1: Response to abnormal Voltage and Frequency**
  - Service Voltage is within ±4% of base voltage (120 volts) at the point of common coupling. Corresponding clearing time is less than or equal to 10 cycles. Voltage set points are adjustable.
  - System Frequency is maintained within +/- 0.5Hz of 60.0Hz. Corresponding clearing time is less than or equal to 10 cycles. Frequency set points are adjustable.

- **Test #2: Synchronization**
  - Voltage fluctuation at the point of common coupling is within the limits of the prevailing voltage level as defined in Table 3.
  - Voltage flicker is less than or equal to 5% and causes no equipment misoperations.

- **Test #3 Interconnect Integrity Test**
  - Influence of electromagnetic interference (EMI) shall not result in a misoperation of the interconnection system.
  - Surge withstand capability is satisfied.
  - Dielectric test across the open-circuited paralleling device proves capability of withstanding 220% of rated voltage.

- **Test #4 Unintentional Islanding**
  - The DR shall detect islanding conditions and cease to energize the distribution system within 10 cycles.

- **Test #5 Limitation of DC Injection**
  - Successful test results conclude total harmonics satisfied per table 4.

Section 4: Interconnection Installation Evaluation

Test #1 Grounding Integration with Area EPS. IEEE 1547-2003 Clause 5.3.1 IEEE 1547-2003 Clause 4.1.2

The grounding scheme for the DR shall not cause overvoltages that exceed the rating of the equipment connected to NorthWestern Energy's distribution system. Additionally, the grounding scheme for the DR interconnection shall not disrupt the coordination of the ground fault protection on NorthWestern Energy's distribution system.

Test #2 Isolation Device. IEEE 1547-2003 Clause 5.3.2 IEEE 1547-2003 Clause 4.1.7

When required by NorthWestern Energy's operating practices for the distribution system, a readily accessible, lockable, visible-break isolation device shall be located between NorthWestern Energy and the DR.

Test #3 Monitoring Provisions. IEEE 1547-2003 Clause 5.3.3 IEEE 1547-2003 Clause 4.1.6

The DR shall have provisions for monitoring its connection status, real power output, reactive power output, and voltage at the point of connection.

Test #4 Area EPS Faults. IEEE 1547-2003 Clause 5.3.4 IEEE 1547-2003 Clause 4.2.1

The DR shall cease to energize NorthWestern Energy's system for faults on the distribution system upstream of the Point of Interconnection.

Test #5 Area EPS Reclosing Coordination. IEEE 1547-2003 Clause 5.3.5 IEEE 1547-2003 Clause 4.2.2

The DR shall cease to energize the NorthWestern Energy distribution system prior to operation of any recloser by on the distribution system.

Interconnection Installation Evaluation Check List

- ❑ Test #1 Grounding Integration with Area EPS.
- ❑ Test #2 Isolation Device.
- ❑ Test #3 Monitoring Provisions.
- ❑ Test #4 Area EPS Faults.
- ❑ Test #5 Area EPS Reclosing Coordination.

Section 5: Commissioning Tests

The following visual inspections shall be performed.

- A visual inspection shall be made to ensure that the grounding coordination requirement of IEEE 1547-2003 Clause 4.1.2 has been implemented.
- A visual inspection shall be made to confirm the presence of the isolation device if required by IEEE 1547-2003 Clause 4.1.7.

Initial commissioning tests shall be performed on the DR interconnection system equipment prior to initial parallel operation. The following tests are required:

- Operability test on the isolation device.
- Unintentional-islanding functionality as specified in IEEE 1547-2003 Clause 5.4.1.
- Cease to energize functionality as specified in IEEE 1547-2003 Clause 5.4.2.
- Any Design Test per IEEE 1547-2003 Section 5.1 that have not been previously performed on a representative sample and formally documented.
- Any Design Test per IEEE 1547-2003 Section 5.2 that have not been previously performed.

The applicable tests of IEEE 1547-2003 Section 5.1 shall be repeated when:

- Functional software or firmware changes have been made on the interconnection system.
- Any hardware component of the interconnection system has been modified in the field, or replaced, or repaired with parts different from the tested configuration.

The applicable tests of IEEE 1547-2003 Sub clauses 5.4.1 and 5.4.2 and applicable tests of Section 5.2 shall be repeated if:

- Protection settings have been changed after factory testing.
- Protection functions have been adjusted after the initial commissioning process.

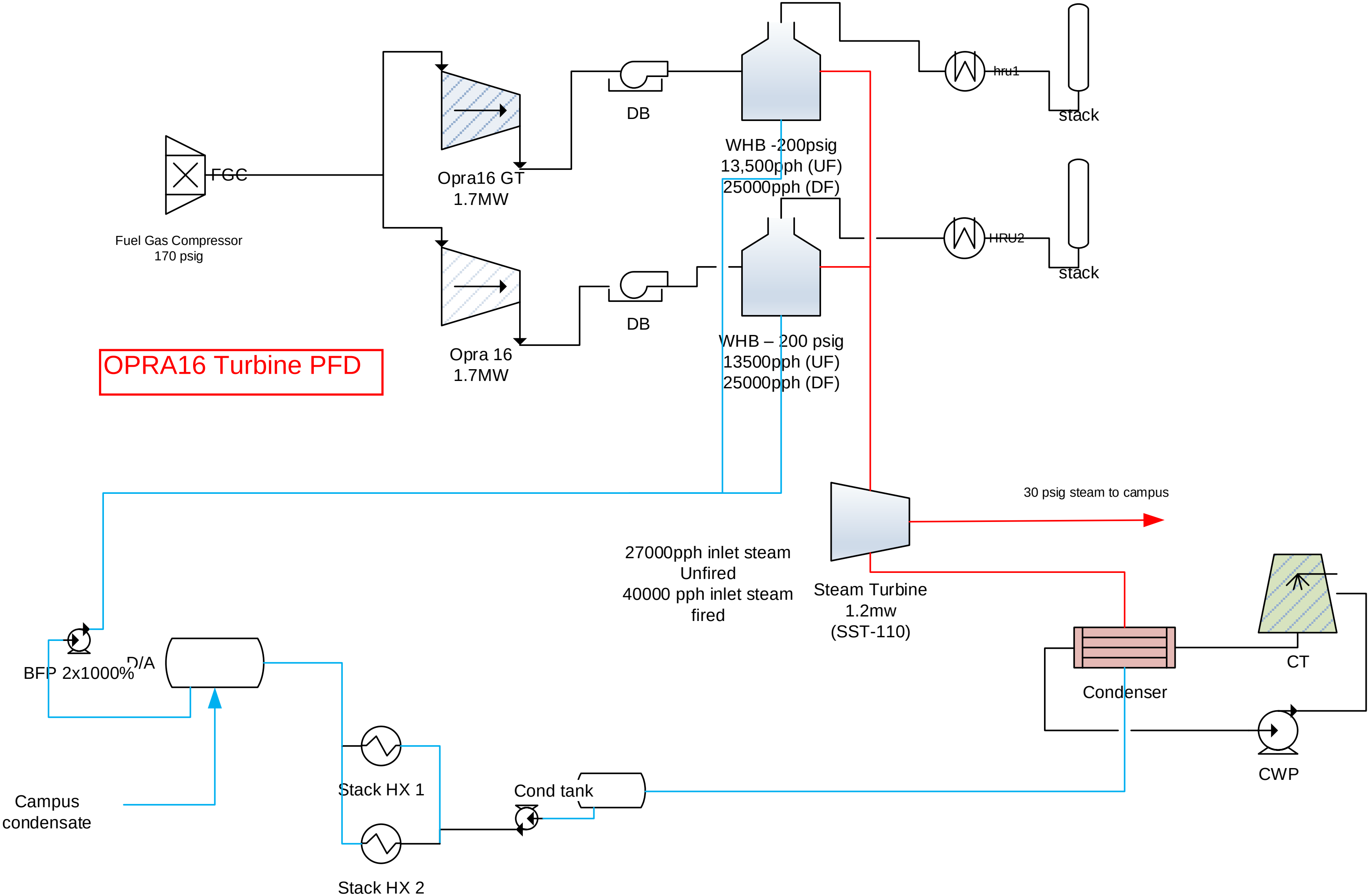
An Unintentional islanding functionality test shall be performed per IEEE 1547-2003 Clause 5.4.1

- A reverse-power and minimum power test shall be performed per IEEE 1547-2003 Clause 5.4.1.1 to meet the requirements of IEEE 1547-2003 Clause 4.4.1.
- A Non-islanding Functionality test shall be performed per IEEE 1547-2003 Clause 5.4.1.2 to meet the requirements of IEEE 1547-2003 Clause 5.4.2.

A Cease to energize functionality test shall be performed per IEEE 1547-2003 Clause 5.4.2. The cease to energize functionality shall be verified by operating a load interrupting device and verifying that the equipment ceases to energize its output terminals and does not restart/reconnect for the required time delay. This test shall be performed on each phase individually. This test verifies conformance to the cease to energize requirements of IEEE 1547-2003 Clauses 4.1.4, 4.2.1, 4.2.2, 4.2.3, 4.2.4, and 4.4.1.

Periodic Interconnection Tests

All interconnection-related protective functions and associated batteries shall be periodically tested at intervals specified by the manufacturer, system integrator, or NorthWestern Energy. Periodic test reports shall be maintained and available to either party at all times.


OPRA16 Turbine PFD
Fuel Gas Compressor
170 psig
FGC
Opra16 GT
1.7MW
Opra 16
1.7MW
DB
DB
WHB -200psig
13,500pph (UF)
25000pph (DF)
WHB – 200 psig
13500pph (UF)
25000pph (DF)
hru1
HRU2
stack
stack
30 psig steam to campus
27000pph inlet steam
Unfired
40000 pph inlet steam
fired
Steam Turbine
1.2mw
(SST-110)
CT
Condenser
CWP
D/A
BFP 2x1000%
Campus
condensate
Stack HX 1
Stack HX 2
Cond tank